TRIBOLOGY

A SELECT ANNOTATED BIBLIOGRAPHY
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BY

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Dedicated to
My Father

CONTENTS

A C K N O W L E D G E M E N T

I express my deep sense of gratitude to my Supervisor, Mr. Shabahat Husain, for his praisworthy guidance, co-operation and encouragement to accomplish this work. The leading ideas and valuable suggestions given by him have immensely helped me during the process of completion of this work. Without his inspiration this bibliography would not have seen the light of the day.

Thanks are also due to Professor Said K. Ayyubi, the then Member-in-Charge, Library & Book Bank, Z.H. College of Engineering & Technology, AMU, who not only advised me to undertake "Tribology" as a subject of Bibliography but also helped me in assigning the subject headings to the highly technical articles.

I am also highly thankful to Professor Noorul Hasan Khan, University Librarian, Professor Sabir Husain, Chairman, Department of Library Science, AMU for their valuable suggestions and encouragement in the compilation of this bibliography.

My thanks also go to all the teaching & non-teaching staff members of the Department of Library Science for their co-operation and help whenever it was needed.

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Shama Parveen

MISS SHAMA PARVEEN

P R E F A C E

Tribology as a branch of Mechanical Engineering is of great and growing importance because it plays a major role in material and energy conservation. With the rapid advancement of industry with higher loads, speeds and temperatures, tribological considerations play a great role. Great savings in cost and materials could be achieved through improved tribological practices.

WHAT IS TRIBOLOGY :

Tribology is the science and technology of friction, lubrication and wear. It deals with friction, wear, lubrication, bearing materials, lubricants and selection and design of lubrication system.

WHY THIS TOPIC WAS SELECTED FOR DESSERTATION :

In view of paramount importance of this fast developing field in Mechanical Engineering I as one of the Library workers in the Central Library of Zakir Husain College of Engineering and Technology, AMU faced quite a significant number of queries on the subject. This made me to realise the significance of this subject. Besides this, I was advised by the then Member-in-charge of Library & Book Bank, Professor Said K. Ayyubi of Department of Mechanical Engineering and also by some other senior teachers of the College to undertake this subject for compilation of an annotated bibliography which, according to them, will not only be useful for the researchers of the subject but will also contribute in my professional progress.

SCOPE :

This annotated bibliography contains 253 entries and is divided into four sections as given below :

	Section	Entry No.
1.	General (deals with tribology, analysis its application, national centers, economic aspect, energy conservation and extra polation in tribology	1-33
2.	Friction	
	" Adhesion, Alloys	34-83
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Section		Entry No.
4.	Wear	190-253
	" Abrasion, Debris analysis	
	" Abrasion, Mathematical Model	
	" Abrasion, Solid particles	

Entries in the bibliographical part are arranged in the alphabetical sequence. An attempt has been made to include the annotations of the latest literature available on the triboloby and its related field upto the first quarter of 1988.

SUBJECT HEADING :

In the absence of any depth schedule of classification and nonavailability of any standard list of subject heading on tribology, attempt has been made to give co-extensive headings as far as possible by using basic principles of assigning subjects. These subject headings along with the entries are arranged in alphabetical order. It will facilitate readers to find out desired article(s) from this bibliography. If more than one entry comes under the same subject heading, these are arranged strictly by the principle of alphabetical sequence. The general pattern of subject headings used in the bibliography is as follows:

TRIBOLOGY

" FRICTION

" " ADHESION

" " ANALYTICAL SOLUTION

To achieve helpful collocation of entries indirect subject headings have been used as shown below :

TRIBOLOGY, LUBRICATION, BEARING, CYLINDRICAL BORE

" " " ELASTOHYDRODYNAMIC,

" " " EXTERNALLY PRESSURIZED, POROUS THRUST

" " " JOURNAL, POROUS

<u>ARRANGEMENT</u> :

The entries are proceded by the subject headings in capitals. Each entry begins with the Entry Element (i.e. surname) of the author in capitals, followed by the secondery Element (i.e. forname) in paranthesis, and then the title of the article, which is followed by the title of the periodical, its volume, issue number, date of publication, after which are given the pages in inclusive notation of the articles. At the end of each bibliographic entry an informative abstracts of the article is given.

STANDARD FOLLOWED :

A great care has been taken to strictly follow the rules and practices of the Indian Standards for Bibliographical Reference (IS : 2381-1963) for each entry of the bibliography. Thus it gives a uniformity, for the bibliographical reference throughout the select bibliography. Attempt has been made to give a maximum abbfeviated form for the name of periodical. The items of bibliographical reference for each entry of a periodical artical are arranged as follows :-

a) Name(s) of author(s);
b) Full stop (.)
c) Title of contribution including sub-title,if any
d) Full stop (.)
e) Title of the periodical in abbreviated form as far as possible.
f) Full stop (.)
g) Volume number
h) Coma (,)
i) Issue number
j) Semi colon (;)
k) Year of publication
l) Coma (,)
m) Date of publication
n) Semi-colon (;)

a) Inclusive pages of the article

SPECIMEN ENTRY :

Entry No. 105, ZAHEERUDDIN (Kh) and AYYUBI (SK). Theoretical study of the effects of solid particles in the lubricant of externally pressurized porous thrust bearings. Wear. 89, 2; 1983, 237-44.

ABSTRACT :

Studies the effect of suspended particles (microstructures) in the lubricant of an externally pressurized porous thrust bearing. The expressions determining the pressure distribution and the load capacity are found to be functions of the parameter h/k, i.e. the reciprocal of the ratio of the average radius of gyration k of the microstructures to the film gap h of the bearing, and the parameters characterizing the porous matrix. The presence of microstructures in the lubricant increases the pressure level in the bearing, and consequently the load carrying capacity of a bearing lubricated with a micropolar fluid is greater than that of a similar bearing under similar conditions lubricated with a non-micropolar fluid. The load capacity also increases as the parameters characterizing the porous matrix increase.

INDEX :

The index part contains an author index and a title index. The ISI rules for Alphabetical indexes are strictly followed for both the indexes. Each index guides to the specific entry or entries in the bibliography. It is hoped that they will be found very useful in consultation of the bibliography.

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PART ONE
INTRODUCTION

INTRODUCTION

Tribology is a newly emerging area of technology which deals with the problems related to lubrication, friction wear and tear of machines etc. Tribology is defined as "a study of the interaction between surfaces in relative motion and of the pratices related there to". It incorporates a multitude of subjects, including friction, wear, lubrication, bearing materials, lubricants, and the selection and design of lubrication systems, and it forms a vital element of engineering. It is not only concerned with the lubrication aspects of machine but also its design and maintenance from the point of views of long working life of the machine. Problems like scuffing, pitting, frettage, cavitation, corrosion, vibration and noise etc. are common with machinery due to wrong choice and method of lubrication. Every machine design is affected by it, for if sound tribological practices are not employed, excessive wear and even breakdown occurs.

GENESIS

The term tribology first appeared around 1960 when David Tabor of Cambridge University suggested it as the answer to a growing dilemma then facing a variety of engineers and scientists. The word Tribology is based on the Greek word, Tribus, meaning sliding seemed to fill the bill as a name that would group their common interest under a more broadly defined discipline.

The first published use of the word tribology appeared in the 1966 Jost report for the U.K.'s Department of Education and Science. Jost later noted that the approach of tribology was new, in that it brought together for the first time such subjects as wear, friction and lubrication as wholly interdisciplinary embracing physics, metallurgy, chemistry, mechanical engineering, mathematics etc.

DEVELOPMENT OF TRIBOLOGY IN PREHISTORIC AND ANCIENT PERIOD

There is little evidence of tribological practices in the early stone age. The first fires made by humens were created by using the heat of friction. In later times hand or mouth held bearings were developed for the spindles of drills, which were used to bore holes and start fires. These bearing were often made of wood, antlers, or bone. Among the earliest mode bearings are door sockets, which were first made of wood or stone and later lined with copper, and potter's wheels, such as one unearthed in Jericho and dated 2000 B.C. It contained traces of bitumen, which might have been used as a lubricant. A considerable development of tribology took place in Greece and Rome beginning in the fourth century B.C. during and after the time of Aristotle. Evidence of advanced lubrication practices during Roman times was provided by two pleasure boats that sank in Lake Nemi, Italy A.D. 50, they contained prototypes of three kinds of modern rolling element bearing. The Middle Ages saw a further improvement in the application of tribological principles, as evidenced by the development of machinery such as the water mill. An excellent account of the history of tribology up to the time of Columbus is given by Dowson.

The basic laws of friction were first deduced correctly by Leonardo da Vinci. The scientific study of lubrication began with Rayleigh, who together with Stokes, discussed the feasibility of theoretical treatment of film lubrication Reynolds gives the theory of lubrication and discussed the importance of boundary conditions. Notable subsequent work was done by Sommerfield and Mitchell. But for many years the difficulty of obtaining three dimensional solutions to the pressure equations of Reynolds impeded the application of lubrication theory to bearing design. This impediment was finally removed with the advent of the digital computer.

Transportation and Tribology :

The real progress in tribology over the year is close paralled with advances in transportation. Transportation, in fact has historically provided the major drive for tribology R & D. Journal bearings were developed to serve the needs of the rail roads; rolling contact bearings were created to improve the bicycle. With the advent of the automobile bearing temperatures increased and wear life requirements lengthened. Lubricant, too evolved from a simple refined oil to a highly sophisticated product containing detergents, friction, modi fiers, wear reduction, additives, dispersants, and oxidation inhibitors. Improves greases have been developed with better corrosion resistance, higher temperature stability, and extended life potential.

From the 1940s through the 1950s, jet engines provided the major impetus behind R & D to develop long life reliable rolling contact bearings. New higher temperature bearing materials and synthetic lubricants were also introduced.

Tribology in Modern Era :

The next stage was to support space transportation which had created problems that brought tribology into a new sphere. The surface of many common materials that slide well against each other without lubrication on Earth simply stick together in space. All of the lubrication normally provided by the contaminating and corrosive elements present in the Earth's atmosphere are not available in space. In addition any applied liquid lubricants are soon dispersed and "pumped away" by the enveloping vaccum of space. Solid lubricants developed because of the need for higher temperature jet engine parts, also became valuable as effective space lubricants since fluids could not be retained on bearing surfaces.

Space research received greatest attention through the 1960s. Soon a lot of these problems were resolved and there was a gap in tribology R & D activity as space research and development work on high temperature bearings for jet engines slackened.

In the present and for seeable future economic situation, material and energy conservation is becoming increasingly important. As wear is a principal cause of material wastage, any reduction of wear can effect considerable savings. Friction is a serious cause of energy dissipation and considerable saving can be made by better control of friction. Lubrication is the most effective means of controlling wear and lowering friction. Thus tribology (the science and technology of friction, lubrication and wear) plays a major role in material and energy conservation.

Energy saving however is not the only new drive behind tribology. Another is to prevent failure and lengthen the operational life of equipment, obtaining doller saving through reduced maintenance.

As time passed more researchers started calling themselves tribologist. Government too began initiating tribology programmes. In 1975 ASME's then lubrication division had established the Bert Newkirk Award to an individual under 35 making a notable contribution to tribology. Recently the ASME changed the name of its 68 year old Research Committee on Lubrication, Journal of Lubrication and Lubrication Division to the Research Committee on Tribology Journal of tribology and tribology division.

It is just over a decade since the word tribology entered the English language with the publication of the lubrication Report (i) and, therefore, a convenient time to assess its current status. Tribology now describes a field that brings together experts from numerous technical background to work together in different problems toward a common end. A recent questionnaire sent out by ASME's Tribology Division has 51 areas of current interest in a check list.

AREA OF CURRENT INTEREST

Friction	Tools	Surface temperature
Lubrication	Cables	Lube film thickness
Wear	Rolling Bearing	Load capacity
Fretting	Engines	Life prediction
Erosion	Seals	Inspection
Adhesion	Gears	Failure analysis
Filtration	Brakes	Diagnostics
Metal Cutting	Brashes	fluid mechanics
Abrasion	Tires	EHD lubrication
Fatigue	Rings	Traction
Bushing	Coms	Oil Analysis
Splines	Orings	Solid lubricants
Conplings	Transmission	Greases
Clutches	Materials	Additives
Valves	Lubricants	Packings
Fasleners	Hydraulid fluid	Gaskets
Hard Surfacing	Wear Resistant etgs	

IMPACT OF TRIBOLOGY

There is a continuously increasing awareness of the subject tribology through out industry. In the United Kingdom National Centre Tribology and industrial units of tribology have been set up to provide expert advise to industry on the utilization of existing knowledge. These centres were provided with Government deficiency grants but are now viable establishments operating as contract research organizations selling their services at commercial rates.

In the U.K., over 30 universities, polytechnics and technical colleges have incorporated cources on various aspects of tribology into their syllabuses A basic Tribology module for undergraduate mechanical engineering courses has been drawn up. Tribology is an elective subject for HNC in engineering, and a tribology content in included in some C AA courses. The iron and steel and Engineering industry training Boards include tribological topics in their recommendations for the training of Craftsmen. Post-graduate research in tribology, leading to higher degrees is carried out at several universities. Three universities have chairs in tribology. A comprehensive selection of cources and training programmes is also available to industry.

Some 700 papers of tribology are now published annually. Most of these reports research directed toward a better understanding of the fundamental principles governing interaction surfaces. A tribology hand book has been produced which presents tribological information to industry in a form that is readily accessble and easily understood by engineering designers, draughtmen and works engineers.

AREAS COVERED UNDER TRIBOLOGY

(1) Lubrication

(2) Friction

(3) Wear

Lubrication :-

Lubrication is an important item for any machine or mechanical device with moving parts and is a subject to the attention of all scientist and Technologist, to a variable degree, from the design department to the shop floor.

Most of the lubricated systems consist two relatively moving surfaces (may be plane or curved, loaded or un-loaded) with a thin film of lubricant between their. The presence of such a thin film between these furfaces helps them to support considerable load and at the same time to minimise the friction. This process of minimising friction between two surfaces by the presence of a thin film is known as lubrication.

The process of lubrication depending upon the operating conditions, may be divided in the following three types :

(a) Boundary lubrication

(b) Hydrodynamic lubrication

(c) Mixed lubrication

(a) <u>Boundary Lubrication</u> :-

When the two surfaces are seperated by a thin hydrocarbon film, shose thickness is of order of the size of the molecules, under this conditions the lubrication is known as boundary lubrication. Under these conditions the behaviour of the sliding system depends upon the combined properties of the lubricant and the solid surfaces in contact. The co efficient of friction in a boundary lubrication lies in the range of 0.08 to 0.14 and wear occurs due to solid to solid contact during siliding.

(b) <u>Hydrodynamic Lubrication</u> :-

In this type of lubrication the two sliding surfaces are completely seperated by a layer of thin fluid film , whose thickness is of the order of 10^{-5} to 10^{-3}cm. Under these conditions,the transport properties of the lubricant offer the sole resistance to the relative motion of the surfaces. The coefficient of friction in the hydrodynamic lubrication is found to be about 0.0001.

Because of its low value of coefficient of friction most of the engineers and designers prefer to mention the conditions of hydrodynamic lubrication.

(c) Mixed Lubrication :-

Where operating conditions cause partial braekdown of fluid film, a situation between boundary and hydrodynamic lubrication occurs in such conditions mixed lubrication take place. The coefficient of friction in this case may be in the range of 0.02 to 0.08. The bearing characteristics depend upon the interaction of the surface asperities and the hydrodynamic action of the film.

The extent and diversity of the applications of the lubrication has made it one of the most complex problems in technology. The tremendous technical developments achieved in the post two decades, has brought with it significant changes in the field of lubrication. A Committee known as Just Committee was appointed in the late sixties by the Ministry of Technology, United Kingdom to investigate the problems, faced by scientist and engineers related to lubrication, friction and wear. It is this Committee which infact gave a new name 'TRIBOLOGY' to the subjects related to problems of lubrications, friction and wear.

Since Reynolds produced his equation, the mathematical expression of the process of film formation between relatively moving surfaces has been fundamental to all lubrication theory. Equations have been fundamen tal to all lubrication theory. Equations have derived and applied to the study of the various surface configuration used in industry. However, it is not until the introduction of the high speed digital computer that a simultaneous solution of Reynolds equation, together with equations representing the variation of viscosity with pressure and the elastic deformation of the surfaces, became a practical proposition.

Optical studies of EHL films, infrared temperature measurement and the elucidation of the response of viscous liquids to high frequency shear have greatly improved the understanding of elastohydrodynamic contacts. Based on the view understanding, a theory of EHL traction has been advanced which may be applied to engineering components such as rolling bearings and variable speed drives.

Progress in hydrodynamic lubrication appears to be centered on detailed developments rather than improved fundamental understanding. Work on boundary lubrication seems to be orinted mainly to specific problems or problem areas such as elavated temperature and hostile environments.

Two centuries of study have failed to unravel completely the mysteries of the lubrication problems most important to mankind the mechanisms of human joints. From the engineer's point of view, the reciprocating engine and a walking human being have in common the need for similar bearings. The tentative proposal of squeeze films made Fein a decade ago and the emphasis is placed by Dowson on protective motion of the simple squeeze film is now supported as the mechanism which dominates the tribologist's desire for a full film of fluid between joints for loads of short duration.

Lubricants :

In the field of tribology, a disproportionate amount of research appears to be carried out on lubricants. When design is inadequate and failure in service occurs, it is commercially more acceptable to change the lubricant rather than the design. Thus, research and development work is continuously directed toward imporoved lubricants and additives to impart or reinforce desirable properties and synthetic lubricants with unique properties. The more recent major development in lubricant formulation of specialized lubricants for extrems environment but also of replacing mineral oil in some traditional applications. Although these fluids may cost about four times as much as mineral oil based products, experience with them indicates that they may give an overall cost saving.

In some applications the complications caused by lubricants lead naturally to consideration of wear resistant materials which possess good frictional properties and which can operate without lubrication. Anti pollution and conservation are placing emphasis on sealed, lubricated for life machinery using solid lubricants and surface treatments which lubricate. The general concept of metal plus lubricant is now giving way to refractory or similar materials plus coolant or parling compound. Under these conditions, techniques for studying and controlling surface structure become important, for as close control of structure and strength is achieved, the performance and wear resistance must depend increasingly on interfacial conditions. The absence of any recognized code of practice and well established tests for evaluating code of practice and well established tests for evaluating new materials for tribological design requirements means that suitability can be reliably established only be performance in practice, and accelerated service simulation testing is now replacing conventional test rigs.

Liquids, solids, semisolids, and gases are used as lubricant.

Liquids :

Lubricants that are liquids at normal temperatures that are liquids at normal temperatures played a minor role until the industrial revolution. Before then greases and paster of animal, vegitable, and marine orgins were the principal lubricants. Liquids provided a fluid film lubricating effect or a thin-film quasi-hydrodynamic effect in machinery and gave better performance than the semisolids. It was found that fluids helped to cool moving parts and remove wear debris from the lubrication area.

There are various types of liquid lubricants they are following :

(1) Natural Falty Oils :

Early liquid lubricants were water insoluble fats and oils derived from plant, animal, and marine sources. They are mostly (95-98") composed of glyceryl esters of falty acids. The more popular fats and falty oils that are used as lubricants are listed in the table.

The principal lubricants in use today that contain fats and falty oils are compounded steam cylinder oils, cutting oils, greases, automotive transmission fluids, air compressor cylinder oils, metal drawing oils, and

Table 9-1 Typical physical properties and chemical composition of fats and fatty oils[a]

Material	Viscosity (μm²/s at 37.8°C)	Melting point (°C)	Iodine value (g/100g)	Saponification value (mg KOH/g)	Fatty acids (% by weight)								
					Saturated					Unsaturated			
					Lauric	Myristic	Palmitic	Stearic	Other	Palmitoleic	Oleic	Linoleic	Other
Animal													
Lard oil	44.4	31	59	195	–	1	28	12	–	3	47	6	2
Neat's-foot oil	43.2	–	72	195	–	–	17	2	–	–	75		–
Beef tallow	–	–	50	197	–	6	27	22	–	–	50	3	–
Marine													
Herring oil	–	–	140	192	–	7	13	–		5	–		74
Menhaden oil	–	–	170	191	–	6	16	0.6	0.6	16		–	61
Sardine oil	–	–	185	191	–	5	15	3	–	12	19	19	48
Sperm oil	23	–	82	125	1	5	7	–		27	37	[illegible]	24
Whale oil	–	–	120	195	0.2	9	16	3		15	35		22
Vegetable													
Castor oil	293	−18	86	180	2.4	2.4	2.4	2.4	–	–	7	3	87
Coconut oil	29.8	25	10	268	45	18	11	2	15	0.5	8	1	–
Cottonseed oil	35.9	−1	106	194		1	28	4	2	2	23	43	–
Olive oil	46.7	−6	81	190	–		–	2		–	84	5	
Palm oil	–	35	54	200		1	40	6	–	–	43	[illegible]	
Rapeseed oil	50.6	−10	99	175	–		4	2	–	–	32	15	51
Soybean oil	–	−16	130	191		–	10	2	1	–	29	51	–

[a] All values except viscosities are from the *Handbook of Chemistry and Physics* 47th ed., Chemical Rubber Co., Cleveland, 1966

industrial gear oils. Falty oils do not adversely affact rubber, as do petroleum oils, and are therefore used as rubber lubricants.

Much of the value of natural fats and oils lies in their use as raw materials forfalty acids, which are highly prized lubricant additives, and cosmetic ingredients.

Mineral Oils :

This includes oils made from petroleum, coal, shale, tar sands, gilsonite, and peat. Petroleum and oils made from petroleum are the important lubricant.

Petroleum oils are excellent lubricants because they (1) wet rubbing metal surfaces (2) are available in a wide range of viscosities, and (3) have viscosities that increase with pressure more rapidly than those of almost all other fluids.

Viscosity :

The constant of proportionality relating fluid shear stress to shear strain Newtonian liquids in the most important property of a lubricant and hydraulic fliid. Because of the relation between viscosity and fluid film thickness in elastohydrodynamic lubrication, this property in significant in determining friction loss, mechanical efficiency, heat generation, fluid flow, load carrying capacity, and wear of machine components such as bearing and gears.

Other Properties :

The next important property of petroleum lubricants is their ability to resist oxidation. This is a function of their chemical composition. Saturated paraffins are much more resistant to oxidation than are unsaturated materials. To ensure longer usage oxidation inhabitors are employed, however, advanced refining techniques have been developedthat produce "super" petroleum oils, which are able to resist oxidation to high temperatures and have other improved properties as well, including VI, additive susceptibility, and low temperature fluidity.

U s e s :

Petroleum oils are used wherever lubricants are needed from internal combusion engines to gears to slideways to metalworking operations. The vast majority of lubricants used are derived from petroleum and their applications are almost limitless An extensive compilation of uses is much beyond the scope of this desertation.

One of the great advantages of petroleum oils is that they are available in a wide range of compositions, providing a wide range of properties. Thus it is relatively easy to make a petroleum based lubricant having the specific properties needed for an application.

Lubricants have other functions besides lubrication such as power transmission, heat transfer, electrical insulation, and solvency.

Additives :

For most applications of petroleum oil lubricants, certain materials must added to provide a new and desirable property that was not originally present, to ehhance a desirable property already possessed in some degree, or to overcome some natural deficiency. Additives are used to reduce thermal and oxidative degradation, lessen the accumulation of harmful deposits, change the viscosity characteristics, minimize rust and corrosion, control frictional behaviour, reduce wear prevent bactarial growth, prevent destructive metal contact, and control foaming. Because of the demands of the automotive market, the bulk of all additives produced finds it way into crank cases, transmission,and rear axle lubricants.

Emulsions Dispersions :

When mutually insoluble materials are mixed, the system is called a dispersion. Generally in the field of lubricants, the term dispersion is applied to a nonsoluble solid mixed with a liquid, such as graphite in oil. When the two components are immiscible liquids, and particularly when a third stabilizing material is included, this dispersion is called an emulsion.

Synthetics :

Because of the technological developments in aircraft, spacecraft, nuclear equipment and other advanced machinery, the best petroleum based lubricants are inadequate, and synthetic lubricants are used in the machinery. Synthetic lubricants are manufactured materials that do not exist in nature. Synthetic hydrocarbons, organic esters, polyglycols, polyphenyl ethers, phosphate esters, silicones, silanes and silicates, halogenated polyaryls, flyorocarbone, are the important synthetics lubricants.

Semisolids :

Semisolids lubricants such as greases, pastes, and soft solid fats and waxes of animal, vegetable, and marine orgin were relegated to use in very crude machinery and areas needing lubrication that could not be designed to hold liquid lubricants in place. Even to-day, semisolid lubricants are generally used only where circulating liquide lubricants can not be contained and where cooling by the lubricant is not required.

Greases :

A lubricating grease is a solid or semifluid product of a dispersion of a thickening agent in a liquid lubricant that may contain other ingredients imparting special properties. The majority of greases are composed of mineral oils thickened with metal soaps.

The viscosity of greases is very non-Newtonian in that it exhibits extreme nonlinearity in the shear rate/ shear stress ration. This factor and semi solid nature of greases are responsible for their advantages and some disadvantages, which include positive lubrication at low speeds, low side leakage from bearings, less sensitivity to load and speed changes, higher viscosity at fixed accentricities, inability to dissipate heat and wear debris, and inability to flow to critical areas at high speeds.

Additives :

To enhance certain properties of greases additives are used. These are generally of the same kind as those used to impart certain properties to petroleum oils. The additives include oxidation, inhibitors, must preventives, extreme pressure agents, antiwear agents, friction modifiers, structure modifiers and sealants. Various types are greases are used as lubricants such as lithium-base greases, calcium base greases, sodium-base greases, alumium - base greases, barium-base greases, lead-base greases-bentone base greases and synthetic greases.

Soaps, Fats and Waxes are also used as lubricants.

Pastes :

Mixtures of soaps and fats with water are sometimes used as lubricants where recirculating fluid systems can not be used and where there is a usedto remove the lubricant at some subsequent point. These inexpensive mixtures are normally found as lubricants in metalworking operations such as wire drawing and sheet forming.

Solids :

Solid lubricants are used under conditions where boundary lubrication prevails because they provide a mere stress-resistant surface than do liquids. They are also used under very high temperature conditions, where liquid normally are not useful. There are also situations in which liquids are not desired because of sealing and containment problems and solids can fill performance requirements and eliminate the problem of containment.

Solid lubricants are used in particulate form as dispersions in oils, greases and gases. They are also used as solid films. The performance of a solid lubricant depends on its properties relative to those of surfaces that it is intended to lubricate and on the physical conditions under which it performs. Thus, some solid lubricants perform well in some circumstances but not in others.

These lubricants will provide successful lubrications in unusual situations for a example, at very high temperatures, in cryogenics, under very high vacuum in nuclear applications, under extreme loads, and in very chemically reactive environments.

Particulates :

A number of materials, mostly inorganic, are used as lubricants in particulate form. They are dusted dry on the surfaces to be lubricated or are dispersed in easily evaporated liquids or gases, in lubricating liquids, in greases, or in composite mixtures. These materials include graphite, molybdenum disulfide, talc, mica, vermiculite, teflon, and other inorganic salts. Ingeneral they have lubricating abilities because of their layered lattice structure and they are usually anisotropic. Their structure allows them to be easily sheared, and therefore they lower the friction when placed between sliding metal surfaces and provide a shear plane of lower strength than those of the two sliding surfaces.

The solid lubricants most commonly used in particulate form dispersed in some media are graphite and molybdenum disulfide. Some quantities of teflon and lead compounds are also used. These materials tend to prevent or delay seizure where the oil or grease film is reptured by high stress or lost for some other reason for a finite time.

Polymers :

Self lubricating films and bearings are made from organic polymers such as nylon, teflon, acetals, polyimides and phenolics.

Teflon and related compounds are lowest in friction of any plastic and as low or lower than other materials. Teflon is heat resistand and chemically inert but is a poor thermal conductor. Teflon tends to transfer to rubbing surfaces and its frictional properties are somewhat directionally oriented. Combination of teflon and phenolic rosins have increased wear lives without increased friction.

Nylon has relatively low friction and good wear resistance. It cold flows under load and swells slightly in humid atmospheres.

Acetals have about the same frictional level against steel as does nylon, but they are less costly, have good strength and stiffness, and shown no tendency to stich-slip at low speeds.

Polyimides have the highest pressure-viscosity rating of the organic polymers. They have good strength and are relatively heat resistant.

Polyethylene films are sometimes used as lubricants in metal processing, where liquid or other solid lubricants are undesirable or unusable. They have good frictional characteristics and are inexpensive.

Soft Metals :

Soft metals such as Tin, Copper, and Lead in the form of plating on steel have been used as lubricants for many years. These materials are used mostly as thin coatings on hard metal substrates and under conditions where vermal lubricants are undesirable or unusable. They are particularly valuable at very high temperatures and under severe environmental conditions, as in metalworking and spacecraft.

Films of gold, silver and other precious metals are used as lubricants in space capsules high performance jet planes, and high speed machines operating under highly loaded conditions.

Surface Conversion Coatings :

Lubrication is the process of providing a low-shear layer between contacting solids. A special way is to convert the surface of a contacting metal to a chemical compound in situ, so that the converted surface has a low shear strength and is very adherent to the metal. This is generally done with metal surfacesthat are difficult to lubricate in ordinary ways or are prone to easily transfer to the other contacting surface. Conversion coatings are used with more conventional lubricants.

The most common conversion coating is phosphate on steel, which is used in wire drawing, extrusion, and sheet forming. Phosphate coatings also provide corrosion resistance and adherent surfaces for bonding lacquers and paints to steel. The most widely used phosphate coatings for steel metal working is the zinc compound.

The phosphate coating on steel is porous and crystalline, The pores act as lubricant traps and reservoirs.

Chemical conversion coatings are also applied to aluminum and magnesium alloys against corrosion. These are generally thin oxides, phosphates, and chromates. During metal working operations, supplemental lubricants are used. Anodizing is an electrochemical process for generating an oxide on aluminum, aluminum alloys, magnesium, tantalum, titanium and zirconium. This oxide is porous and has been used to a limited extent for pretreatment prior to lubricant application.

Gases :

Gases or vapours can be used as lubricants under the proper circumstances. The principle use of gases as lubricants is in air bearings.

FRICTION

Whenever two solid bodies in direct or indirect surface contact are made to slide relative to one another, there is always a resistance to the motion which is calledfriction. in beneficial in many instances and we may increase it. life would be impossible without friction. But in other cases friction is energy-consuming and it is necessary to decrease it if not eliminate it entirely.

Friction is present in all machinery and it converts part of the useful kinetic energy to heat, thus decreasing the overall efficiency of a machine. About 30% of the power in an automobile and about 1.5% in a modern turbojet engine is wasted through friction. So it is important to decrease the friction. The real trouble is the damage that is done by friction : the wear or seiquve of machine components and the surface damage caused by frictional heating.

Adhesion :

If the metallic materials are free of surface contaminants, adhesion will occur at the asperity-contact interfaces. This can be demonstrated only for specimens pressed together in a very high vacuum so that the formation of moisture films, organicfilms, or oxides is virtually precluded. For relatively soft materials adhesion can be demonstrated experimently.

W E A R

Wear is defined as an unwanted removal of solid materials from surfaces under relative movement. Wear may be divided in the following four types :

(1) Adhesive Wear

(2) Abrasive "

(3) Corrosive "

(4) Surface fatigue

(1) The adhesive wear arises from a lump removal of materials due to process of solid phase welding.

(2) The abrasive wear may be cutting caused by hard asperities or hard particles.

(3) The corrosive wear or the oxidative wear occurs in the form of a layer removal of corrosion products by mechanical acti on.

(4) The surface fatigue is detachment of particles by fatigue which arises from cyclic stress variations.

The first three occur under sliding motion and the last one under rolling motion.

Mechanisms of Wear :

Progress in wear control and prevention can only be made when a better understanding of the mechanisms by which it occurs has been achieved and the dominent controlling factors have been established.

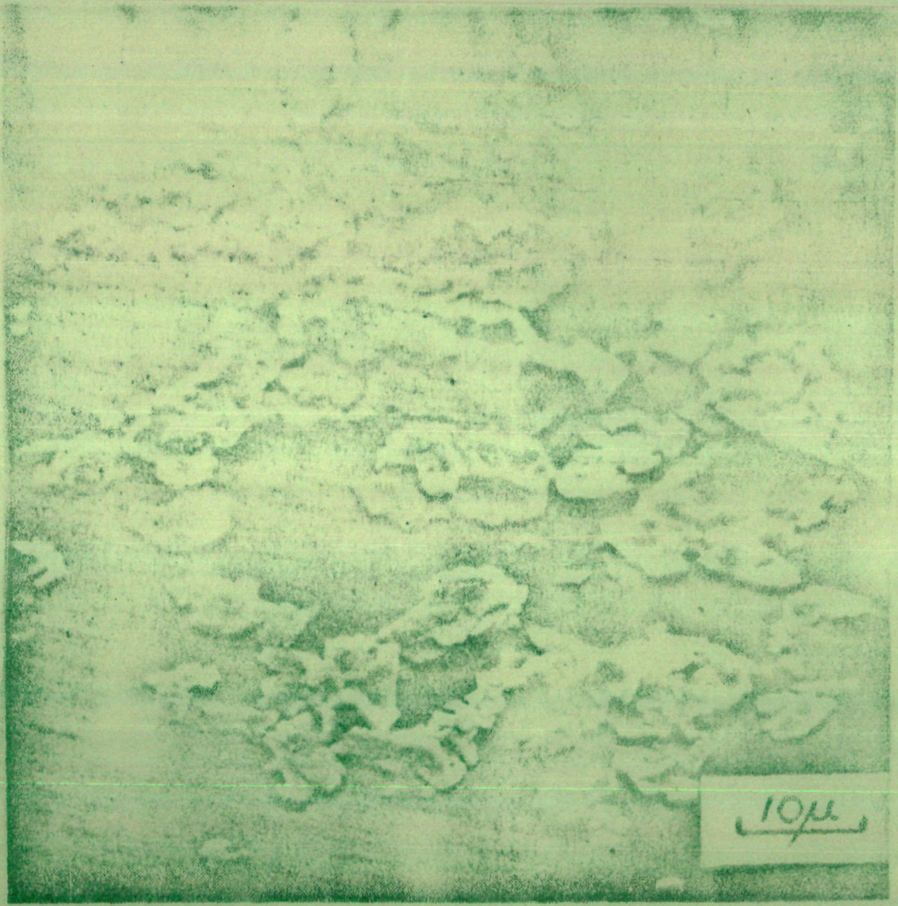

Fig. 1.-Plate like particles of rubbing wear.

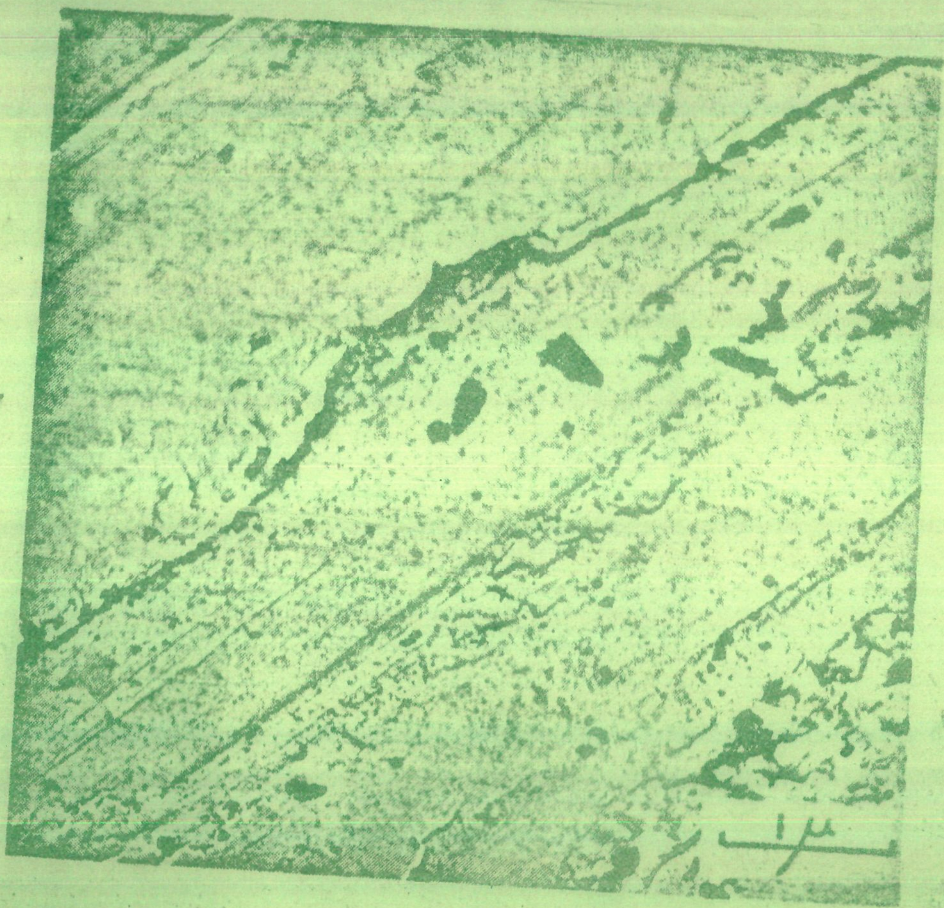

Fig. 2.—Flowed surface layer formed by running in.

The ultimate formation of the wear particle depends on two mechanisms, void formation and crack propagation. For materials such as medium tensile strength steels of good fracture toughness, where void nucleation can readily occur, crack propagation may be the controlling mechanism. However, for materials of high tensile strength and low fracture toughness, void nucleation can be difficult, but crack propagation can readily take place. Void nucleation may then be the controlling mechanism.

SURFACE STUDIES

The friction and wear behaviour of materials is greatly dependent upon the topography, chemical deposition, physical structure and mechanical properties of surfaces and surface material. Contact between surface by relative motion causes charges in these properties which may be of significance in subsequent contacts. Greater attention is now being given to size, morphology and structure of wear particles as well as to the localized nature of dewage to surface, interface and subsurface material. A number of new tools are available for the study of surfaces at atomic level, notably Auger electron spectroscopy, X-ray photoelectron spectroscopy, scanning ion spectroscopy and ion scattering spectroscopy; with complimentary information from X-ray energy analysis in the scanning electron microscope and microprobe analysis, these tools aid the tribological elucidation of surface phenomena.

During the past decade, rapid strides have been made in the application of statistical techniques to the characterization of rough surfaces. The entire statistical microgeometry of certain rough surfaces can now be described in terms of the number of speaks and mean line crossings counted on a single profile. These techniques are now being applied in tribology.

MATERIALS FOR TRIBOLOGICAL APPLICATIONS

The major incentive for the development of wear resistant materials and the acquisition of materials data in the emergence of new design concepts for instance, the aero-space industry spawns new problems and solutions while each generation of nuclear reactors requires some new wear resistant material. Thethermal and stress problems associated with advanced tribo engineering require materials of high strength, high elastic modulus, and light weight. New type of material such as composites, synthetic diamond and sapphire, new graphites and carbides, borides and nitrides of certain metals which approach the hardness of diamond are being developed. Ust of such materials requises new design concepts to utilize their spacific properties, as substitution of such materials in existing designs can lead to problems and failure in service. Besides replacing metals, ceramics may be used as coatings to complement desirable metal characteristics by adding refractory properties, insulation and erosion, wear, oxidation and corrosion resistance.

In the field of plastics the development of bearing materials capable of being manufactured to achieve and maintains the achieve and maintain the close tolerances of metals may cause something of revolution in the plain journal field:

Plastics and their composites dominate the dry bearing due to the availability of design and performance data. The rate of wear depends on the counterface topography and composition generated by the sliding process and involving transfer of polymer or fillers, abrasion by fillers or corrosion by the environment or polymer degradation products. The development of vacuum deposition techniques such as sputtering, ion-implantation, ion plating and CVD processes appear potentially attractive for solid film lubricant solution to a wide range of dry bearing problems.

In the field of rolling bearings material, methods are being developed to improve contact fatigue resistance.

Development in high speed tool steels for rolling bearing have centered around alloys produced by the powder route to provide a finer dispersion of carbides. In the field of cutting tools, ceramic materials such as silicon nitride is developed.

Breakes and clutches are required to dissiplate continually greater energies due to generally increasing loads and speed, and improved materials are constantly being demanded to cope with the higher duties and temperatures. For over seventy years asbestos has been the most effective filler material for phenalic resins, both because of its fibrous nature and its heat resistance. Because of a possible health hazard threr is considerable pressure to replace asbestos with other fillers. Sintered metal matrices are used when the duty is severe. More exotic materials have been successful in aircraft brakes.

SURFACE TREATMENT

Recently developed surface treatments involving this surface films with specific properties are now finding increasing use and are proving to be advantageous as wear resistant coatings. The treatment include physical and chemical vapour deposition processes. The physical vapour deposition (PVD) processes are evaporation Ion plating and sputtering. Metal films deposited by ion plating are strongly handed to the surface as the film is deposited on a surface cleaned by sputter etching. Due to the velocity of the evaporant, the surface is pretended, and a graded interface is formed to give a strongly adherent film. Soft metal lubricant films may also be bonded to a metal surface by ion-plating. Ion nitriding may be used to speed up the nitriding process.

The chemical vapour deposition process deposites carbides of the transition metals on steel. The transition metal in the form of a volatile chloride is carried to the surface by a carrier gas together with a gaseous hydrocarbon. These react at the steel surface to form a carbide layer which is smooth, continuous and wear and corrosion resistant. Tie coatings on sintered carbide cutting tools considerably reduce tool wear. Low temperature CVD processes and controlled nuclear thermochemical deposition have been developed. Ion implantation is a important technique to improve wear resistance.

COMPUTER AIDED DESIGN

Tribology stands between pure science on the one hand, and the material and engineering requirements of technological progress on the other. Rapid technological progress will be achieved only by the improved scientific understanding and the most purposeful, speedy application of scientific knowledge. A major difficulty has been the delay or lack of feed back. To eliminate such delays, increasing use is being made of the computer in design to enable almost instantaneous feed back. Designers and researchers can now communicate directly with the computer. For example, in the field of plain bearings with a suitable constructed program, the designer need only transmit information on bearing design, and within seconds he will be informed of the performance characteristics. In this way he can have instant feed back and can make use of the latest available research results without being an expert in the fields of tribology, computation or programming.

The use of computers for materials selection for optimum performance is approaching rapidly.

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PART TWO
BIBLIOGRAPHY

2.1 LIST OF PERIODICAL DOCUMENTED

Name of Periodicals	Abbreviations	Frequency	Published Place
1. Applied Mathematics & Mechanics	Appl Math Mech	Monthly	US
2. ASLE Transactions	ASLE Trans	Quaterly	US
3. Automotive Engineering	Automot Eng.	Bi-Monthly	England
4. Chemistry and Technology of fuels & oils	Chem Technol Fuel Oils	Monthly	US
5. Engineering Materials and Design	Eng Mater Des	Monthly	UK
6. Experimental Techniques	Exp Tech	Monthly	US
7. IBM Technical Discloser Bulletin	IBM Tech Discl Bull	Monthly	UK
8. Indian Journal of Pure and Applied Physics	Ind J Pure Appl Phys	Monthly	New Delhi
9. Indian Journal of Technology	Ind J Technol	Monthly	New Delhi
10. International Journal of Mechanical Sciences	Int J Mech Sc	Monthly	US
11. International Journal of Solids and Structures	Int J Solids Structures	Monthly	New York
12. International Metals Reviews	Int Met Rev	Bi-Monthly	London
13. Iron Age	Iron Age	Quaterly	UK
14. Israel Journal of Technology	Isr J Technol	Quarterly	Jerusalem
15. Japanese Journal of Applied Physics	Jpn J Appl Phys	Monthly	Tokyo
16. Journal of Applied Metal working	J Appl Metal Work	Twice Annually	US

17.	Journal of Applied Physics	J Appl Phys	Monthly	Tokyo
18.	Journal of Engineering Physics	J Eng Phys	Twice Annually	
19.	Journal of Japan Society of Lubrication Engineers	J JSLE	Monthly	Tokyo
20.	Journal of Material Science	J Mater Sci	Monthly	London
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LIST OF SUBJECT HEADINGS

TRIBOLOGY

" ANALYSIS, ANISOTHERMAL FLUID FILM

" " SCANNING ELECTRON ACOUSTIC MICROSCOPY

" " SELECTION OF MATERIALS

" " TRIBOTEST

" APPLICATION, CHEMICAL VAPOUR DEPOSITION

" BIBLIOGRAPHIC SURVEY

" CENTRE, U.K.

" DATABASE, EVALUATION

" " SYSTEM, DESIGN

" ECONOMIC ASPECTS

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" " " U.K.

" EVALUATION

" " COMPUTER MODEL

" " RESEARCH IN MECHANICAL SYSTEM, USA

" EXTRAPOLATION

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" " ANALYTICAL SOLUTION, PLOWING FRICTION COEFFICIENT

" " ASPERITY CONTENTS, FLASH TEMPERATURE

" " ASSEMBLIES, RELIABILITY

" " BEARING, SYNTHETIC FIBER BASED

" " CAPILLARY SYSTEM

" " CONTACT, INCREMENTAL CONSTITUTIVE, RELATION

TRIBOLOGY, FRICTION, SLIDING SURFACE, FORCE OSCILLATIONS

" " " TRIBOLOGICAL TEXTURE

" " "

" " SQUEEZE FILM EFFECT, INVESTIGATION, STICK SLIP

" " STICK SLIP MOTION

" " STUDY, ADDITIVES

" " " CONTACT AREA

" " " DIFFERENT MATERIALS

" " " ENERGY BASED MODEL

" " " MICROSCOPIC RESISTANCE

" " " OIL GROOVES

" " " ROLLING

" " " SOFT THIN MATAL FILM

" " SURFACE MELTING, NUMERICAL MODEL

" " " STRESS, COMPUTER MODEL

" " TESTING, ANTIFRICTION MATERIALS

" " " BRAKE DYNAMOMETER

" " " MACHINE

" " TRANSFER FILM THICKNESS

" " VISCOUS, ASYMPTOTIC STOPPING

" LUBRICATION, ADDITIVES, ALCOHAL FUELS, DETERGENT

" " " CHEMICAL SULFIDES

" " " CHEMISTRY

" " " COLD FORGING

" " " DETERGENT DISPERSANT

" " " ETHYLENE GLYCOL FLUIDS

TRIBOLOGY, LUBRICATION, ADDITIVES, HIGH ALKALINITY SULFONATE

" " " INTERACTION, SYNERGISTIC EFFECT

" " " KINETIC ASPECTS

" " " MOLYBDENUM CONTAINING DITHIOPHOSPHATES

" " " POLYPHENYLENE SULFIDE, CARGON FIBER DAMINATE COMPOSITES

" " " SERVICE LIFE

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" " " ZINC DIALKYL, DITHIOPHOSPHATES, LUBRICATING OIL

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" " " ELASTOHYDRODYNAMIC

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" " " EXTERNALLY PRESSURIZE POROUS, GAS LUBRICATED

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" " " " " POROUS THRUST, THERMAL CHARACTERISTICS

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" " TRIBOSPECTORAL CHARACTERISTICS

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TRIBOLOGY

1. BARTZ (WJ). Tribology, lubricants and lubrications Engineering : A review. <u>Wear</u>. 49, 1, 1978, 1-18

Evaluates more than 200 papers published between 1974 and 1976. Deals with the fundamentals of friction wear and lubrication including the state of friction lubrication and materials. Another important subject in the analytical data and properties of mineral oil and synthetic lubricants, lubricating greases, additives and solid lubricants. Lubrication systems and lubricating devices as well as the lubrication of bearings, gears and internal combustion engines are also covered. Discusses lubricants for machining processes and for metal working and questions concerning the testing and evaluation of lubricants.

2. BREDIN (Harold W). Directions in tribology. <u>Mech. Eng</u>. 105, 10, 1983, 52-56.

Gives a concise report of the historical back ground of tribology. The word tribology first appeared in the 1966, Jost report for the U.K's Department of Education and Science. Jost later noted that the approach of tribology was new. It brought together for the first time such subjects as wear, friction and lubrication as wholly inter diciplinary-including Physics, Metallurgy, Chemistry, Mechanical Engineering, Mathematics etc. Progress in tribology over the year will show a close parallel with advances in transportation. Transportation, in fact has historically provided the major drive for tribology. R & D journal bearings were developed to serve the needs of the railroad, rolling contact bearings were created to improve the bicycles. With the advent of the automobile, bearing temperature increased and wear life requirements lengthened. Lubrication too evolved from a simple refined oil to a highly sophisticated product containing detergents, friction modifiers, wear reduction additives, dispersants and oxidation inhibitors. Improved greases have been developed with better corrosion resistance, higher temperature stability and extended life potential. Unlubricated composites, wear resistant and friction reducing coatings, improved metal and ceramic bearing materials. Maintenance by condition monitoring and new CAD program advance to-day's designs.

3. CZICHOS (Horst) Current aspect of Tribology. Wear 77, 11, 1982, 1-.

Discusses some aspect of tribology. Briefly covers development of tribology on international level. In Europe several Societies have been established on tribology. USA, Australia, Japan, China plays an important role in the field of tribology. A research programme by FRG on the basis of classifications of BAM tribology documentation was carried out to obtain the main results. In addition a system of descriptors was also developed. different combination of material was used for the development in tribology. The future development in tribology is based on the work of FRG-OECD. The main purpose of FRG-OECD is to contribute to the conservation of energy and materials through international cooperative research work on wear of materials and engineering systems.

. CZICHOS (H). Towards a general theory oftribological systems. Wear. 44, 2; 1977, 247-64.

An approach toward a general coherent description of the function and structure oftribolobical systems in attempted. The analysis starts with the technical function of the system together with an identification of operational, variables in the relationship of the system to the environment. The tribological structure in this represented on separate conceptual planes, one for each type of quality transmitted in the system, i.e. work, entropy and the several materials. Process occur solely as translations on one such phere or as transformations between different types of quantities, each process being governed by certain element properties. Discusses the properties of elements relating to a loss of useful work through friction and vibration. Also discusses those properties relating to entropy transport and those relating to material translation and transformation, i.e. process in wear. Also indicates the interdiciplinary requirements for the study of the tribology of material systems.

5. CZICHOS (Horst). Tribology: Scope and future directions of friction and wear research. Journal of Metallurgy. 35, 9; 1983, 18-20.

Outlines the possible directions of future research on friction and wear. Since friction is responsible for a major loss of useful mechanical energy and wear is a major reason for replacing equipment, a better understanding and utilization of the principles of tribology is important for conservation of energy and materials in engineering design.

6. FELLER (HG). Interactions in metallic tribo-contacts. Metall. 37, 3; 1983, Mar, 248-54.

Presents a review on the surface interactions in metallic tribo-contacts with regard to adhesion, friction and wear. Gives some suggestions for further research.

7. HALLING (J). Tribology : Science and Practice. Phys Technd. 8, 3, 1977, 116-22.

The science of tribology concerns itself with problems of friction, wear, lubrication and contact mechanics. The subject is not new-only the name and the modern interdisciplinary approach are novel. Here a prominent practitioner and another in the field describes current scientific understanding of contact and lubrication phenomena and their practical significance.

8. HAYS (Donald F). Research in mechanical systems : Tribology. J. Tribol Trans ASME. 106, 1, 1984, 14-23.

Describes the role of mechanical systems in industrial productivity from wiving raw materials through transportation, manufacture, packaging and handling. These dynamic systems and controlled systems are all composed of inumerable combinations of interacting surfaces. Tribology in the science of interacting surfaces in relative motion. Tribology, as a science embraces the field of friction, lubrication and wear.

9. LARSEN (Raymond J). Tribology : The little known science of friction and wear. Iron Age. 221, 44; 1978, Nov. 51-4.

Highlightes the new advances in the field of tribology the science of friction, wear and lubrication. Tribological studies are designed to help in the development of new ways to conserve petroleum-based rolling oils, and oils that doe not rely on a petroleum base. Other tribological studies focus on the development of low air polluting lubricants for metal forming, the selection of lubricants for not forging and the reduction of machining costs.

10. LING (FF). Position paper on tribology. J tribol trans ASME. 106, 1; 1984, 24-25.

Emphasis on technological relevance of tribology. Also discusses its role in mechanical engineering and research needs and opportunities.

11. SCHWARZENBACH (J) and DOWSON (D). A final year undergraduate lecture course on tribology. Wear. 38, 1; 1977, 153-63.

A syllabus is presented for an integrated lecture course on tribology for the final year of an undergraduate honours degree scheme. In this course subject

can be treated in depth to provide on understanding of tribology useful to the professional engineer. The merit of such a course is greater than just the transmission of tribological information to the student. Also illustrate important characteristics of many technological disciplines.

12. SUKURAI (Toshio). Recent research on tribology in Japan Wear. 100, 1-3; 1984,Dec, 543-60.

Gives a detailed account of the recent developments in tribology such as the effect of surface irregularities on the lubricating performance in fluid film lubrication and increase infriction in high speed bearings due to turbulent flow. Elastohydrodynamic lubrication and its related problems such as traction play an important role in the lubrication of cams and followers, rolling contact bearings and traction drives. The rheology of lubricants at high pressure is ohe of the most important properties governing lubricated concentrated contacts. Regarding basic studies on wear, the mechanism of the adhesive wear process is being studied. It also investigates the deformation behaviour of materials and structure by finit element method. The friction and wear characteristics of plastic and composites have been studied in basic terms.

13. THOMAS (TR) and SAYLES (RS). Some problems in tribology of rough surfaces. Tribology International. 11, 3; 1978, June; 163-68.

Outlines that parameters such as slopes and curvatures are not intrinsic properties of a surface profile but depend on sampling techniques. Because of the nonstationarity of real surfaces, mere fundamental parameters such as roughness and Correlation length are also nonintrinsic. This leads to the concept of functional filtering", where the roughness used is that of a hard width of profile wave lengths defined by practical problem is hard. Describes and discusses the applications to tribological problems such as the contact of journal and roller bearings and the stiffness of machine tool joints. Also proposes a typology of run in surfaces based on a random process characterization. Finally, the application of discriminant analysis to problems not amerable to direct theoretical treatment is discussed and illustrated by an investigation of the failure of lip seals.

14. WRIGHT (Graham). Tribology twenty years on S. Afr. Mech. Eng. 36, 4; 1986, 98-104.

Discusses the origin of the concept of tribology, its nature, scope and issues which are crucial for its future development.

15. YUST (CS) Tribology and wear. Int. Met Rev. 30, 3; 1985, 141-54.

Provides an overview beginning with a discussion of the tribosystem concept and consideration of the separate elements of such systems. Discusses the physical and chemical characteristics of surfaces as is the combination of surface to form a tribological contact. Examines the role of lubricants in the tribosystem by the technique employed for the physical and chemical analysis of tribology phenomena. Indicates the potential for modern analytical techniques to understand the surface and subsurface processes at interfaces. Reviews wear mechanisms and prospects for energy conservation through tribological improvements.

ANALYSIS ANISO THERMAL FLUID FILM

16. PINKUS (Oscar). Aniso thermal fluid films in tribology. Ist. J Technol. 22, 2-3; 1984-85; 120-41.

Reviews the present status of thermal analysis in the area of anisothermal fluidfilms in tribological processes. It first describes the objective difficulties in both their physical and mathematical sense, and examines the various approaches, investigators have taken to cope with the complexity of the thermal problems. While on anisothermal approach is madatory for a correct evaluation of performance of bearings or seals, and while such an approach is required to arrive at the value of the vital quantity of maximum temperature, the solution obtained by great variety of methods and approaches in the literature differ not only quantitatively,but also qualitatively.

-, -, SCANNING ELECTRON ACONSTIC MICROSCOPY

17. HOLSTEIN (WL) and SCHMIDT (FE). Characterisation of tribological surfaces by scanning electron aconstic microscopy. Wear. 116, 1; 1987, 119-29.

Describes a new technique SEAM for analyzing wear surface. Its ability to detect subsurfaced flows in particularly useful for studying the wear processes where surface and subssurface cracks play a role : surface fatigue wear, spalling, stress corrosion cracking. Includes examples to illustrate the origin and interpretation of scanning electron aconstic micrographs and the use of the technique in the study of wear.

-, -, SELECTION OF MATERIALS

18. KLOOS (KH), Material selection and material pairing, tribotechnical considerations. Wear 34, 2; 1965, 95-107.

Deals with the examples of cutting, plastic processing, shrink fits and gears. It has been shown that numeinteractions depending on the proximity conditions of the friction partners. These are characterized by the collective action of several wear mechanisms. Simulation test method can only provide reliable information toward the functionally reliable selection of materials when the mechanical, thermal and chemical stressing conditions in the test apparatus can be closely adopted actual stressing conditions.

-; -; TRIBOTEST

19. SEIF (MA), MOSLEHY (FA) and RICE (SL). Dynamic stiffness analysis in tribo contact. Wear. 119, 3; 1987, 353-68.

Defines dynamic stiffness and describes its significance in tribotest apparating. A methodology in developed whereby alternative tribotester design can be compared for performance in the area of dynamic stiffness or response. Two specific designs, a governor mechanism and a lever-dead-weight system are compared.

APPLICATION, CHEMICAL VAPOUR DEPOSITION

20. HINTERMANN (HE). Chemical vapour deposition applied in tribology. Wear. 47, 2; 1978, 407-15.

Emphasis is on chemical vapour deposition which is a powerful industrial tool for making functional surfaces resistant to corrosion and wear. It is, useful in bearings, in precision instruments, in deep drawing tools and in cemented carbide cutting tools. Types of coatings developed for chosen substrates and illustrated with the help of examples which shows the advantages of the composite materials.

BIBLIOGRAPHIC SURVEY

21. KALPAKJIAN (Serope). Reference in metal working processes: tribology (friction, lubrication and wear). J Appl Metal Work. 1, 3; 1980, 61-4.

Deals with the reference literature on tribology and its related aspects such as friction, lubrication and wear. Gives information on funcamental aspects lubricats and lubrication, wear and its control and testing method.

22. CENTRE U.K.

ROBERTS (WH). Tribology and industry in the United Kingdom. Lubr Eng. 38, 2; 1982, 93-98.

An outline is given of the background to the setting up of the three UK tribology centres, and brief reference is made to the pattern of their activities in providing industry with advice and assistance. Case history examples from the national Centre of Tribology, Risely, are given which provide pointers to identifying areas of work for continuing research in sphere of tribology. Also emphasizes the importance of collating and presenting technological information in a form which the design engineer in industry can more readily use.

23. ROBERTS (WH). National Centre of Tribology : Some experiences of services to industry since 1968. Inst Mech. Engg. Proc. 188, 62; 1974, 715-25.

N.C.T. has dealt with virtually every industry. Presents an analysis ofthe use made to its consultancy and R &D services by equipment manufacturers and by plant users, and by large and small companies. Gives examples to illustrate the great diversity of problems encountered, both in application and scale.

DATA BASE, EVALUATION

24. FRIES (JR) and KENNEDY (FE). Bibliographic data bases in tribology, J Tribol Trans ASME. 107, 3; 1985, Jul; 285-95.

Reviews computer based information retrieval systems in engineering and specifically focuses on databases of literature and information relevant to tribologist and lubrication engineers. These data bases are listed and their characteristics are discussed. Results of a sample computer based literature search is included. It is shown that no single data base has complete coverage of all aspects of tribology. Several data bases should be searched to get all available information on a subject.

SYSTEM DESIGN

25. TALLIAN (TE). Tribological design decision using computerized database. J. Tribol Trans ASME. 109, 3; 1987, July; 381-87.

Describes the content and structure concept of the tribology data base system. Emphasis is on tribology and computerization aspects of creating a database system. Considers the tribological problem as a design describes in detail the design of the entry module which is a part of the design methods data base element. It is necessary for the completion of the production phase. Also discusses progress towards the prototype phase which demonstrate the design concept.

ECONOMIC ASPECTS

26. Jost (Peter H). Economic impact of tribology. Mech Eng. 97, 8; 1975, 26-33.

Describes economic impact of tribology. Friction and wear causing mechanical failures and maintenance problems normally have their roots in phenomena based on tribology, the science and technology of interacting surface in relative motion. Developments in tribology since 1966 have utilized existing and new knowledge from physics, chemistry, mathematics, statistics, engineering, etc. As a result advances in diverse field from metal working to medicine or space technology, have been produced. The economic benefits that may accrue to industry can be substantial. In the case of US the savings obtainable through tribology could amount to as much as $16 billion per annum. Some of means used in the UK in order to reap the benefits attainable by application of the principle of the multidisciplinary subject of tribology, and some of the results obtained are described.

ENERGY CONSERVATION, U.K.

27. JOST (Peter H), Energy saving through tribology : A techno-economic study. J. Proc Inst Mech. Eng. 195, 6; 1981, Jun 151-73.

The paper tries to determine whether tribology can play a significant part in energy conservation in the United Kingdom and to ascertain if and to what extent, the findings and conclusions of others were applicable to the U.K.

ENERGY CONSERVATION, U.S.

28. PINKUS, (Oscar) and WILCOCK (Donald F). Role of triboloby in Energy conservation. Lubr Eng. 34, 11; 1978, 599-610.

A review of the energy situation reveals that the U.S. in the world's largest absolute and percapita consumer of energy. Moreover nearby 50% of the total energy input into the economy is discarded. Two major energy users, the automotive vehicle and the steam turbine power plant, are identified as consuming over forty per cent of the total U.S. energy needs much of which is not usefully exploited. It is shown that tribology can play an important role in bring about both direct energy savings as well as an indirect benefits. Discusses an R & D plan in tribology which when realized and implemented offers a potential saving of 11% of total U.S. energy consumption.

EVALUATION

29. FUKS (GI) and FUKS (IG). Surface phenomena and tribology problems. Sov J Frict Wear. 5, 1; 1984, 141-44.

Discusses sufface phenomena which contribute the process of friction, wear and lubrication. The adhesive component of the dry friction force and the formation and properties of the boundry lubricant layer depend on these phenomena. Because of the surface phenomena the determination of dry friction becomes very difficult. The process of oxidation and absorption of moisture take place on the surface of the metal and other material of contacling bodies from the liquid or gaseous medium. The cleaning of surface is experimentally very difficult problem.

30. KRAUSE (Hans) and SENUMA (Takehide). Investigation into the influence of dynamic forces on the tribological behaviour of bodies in rolling/sliding contact with particular regard to surface corrugations. J lub Technol Trans ASME. 103, 1; 1981, 26-34.

Influence of the action of a dynamic force on the tribological behaviour of bodies in rolling/sliding contact without lubrication was examined both experimentally and theoretically. The coefficient of traction and the wear both decrease as the amplitude of the dynamic normol force increases. This phenomenon is explained with the aid of a torsional oscillation model. Also discusses the mechanism of ripple formation on a plain carbon steel in the preference of slip using the some model. The ripple originate from the formation of oxide stripes and their further development dependent on the stress condition. It is determined to varying degrees by the plastic deformation and by the periodic wear conditioned by a motion similar to that of stick stip. Because of the different dynamic condition the coefficient of traction measured on a railway locomotive.

COMPUTER MODEL

31. MCCOOL (JI). Tribos : A performance evaluation tool for traction-transmitting partial EHD contacts. ASLE Trans. 29, 3; 1986, Jul, 431-40.

Describes a computer model for performing a state of the art tribological assessment of the performance of a lubricated concentrated rolling/sliding/spinning/ contact comprising general arisotropic rough surfaces. The name chosen for this program is TRIBOS. The program is a synthesis of computational tools from the current literature for the computation of fluid film thickness and traction and a general asperity simulation model for the elastic contact of anisotropic rough surfaces.

RESEARCH IN MECHANICAL SYSTEM

32. WINER (WO). Research needs in mechanical system-Report on the select panel on research goals and priorities in mechanical systems. J Tribol Trans ASME. 106, 1; 1984, 2-4.

Deals with ASME report on mechanical engineering and applied mechanics. Recommendations concerning the National Science Foundation mechanical system programme is also given. Tribology is a major component of their programme. Summary of the entire report and report on tribology are included. Tribology related sections giving a brief description of the descriptive, recommended research needs in tribology, and report of the select panel in tribology.

EXTRAPOLATION

33. GODET (Maurice). Extrapolation in tribology. Wear. 77, 1; 1982, Mar; 29-44.

Discusses the difficulties encountered in attempting to extrapolate friction and wear data, obtained on laboratory rigs to industrial problems in the light of the three body model. Third body teheology together with explicit transverse and longitudinal boundary conditions, are necessary before extrapolation. Various domains of tribology (thick film lubrication, solid lubricants, dry bearings etc.) are explored to see how much of the information required for extrapolation is available in each domain. Simulative testing must be undertaken when extrapolation requirements are not met.

FRICTION, ADHESION, ALLOYS

34. MIYOSHJ (Kazuhisa) and BUCKLEY (DH). Adhesion, friction and wear of binary alloys in contact with single-crystal silicon carbide. J Lubr Technol Trans ASME. 103, 2; 1981, Apr; 180-87.

Sliding friction experiments were conducted with various iron base alloys in contact with a single crystal silicon carbide surface in vacuum. Results indicate atomic size misfit concentration of alloying elements play a dominant role in controlling adhesion, friction and wear properties of iron-base binary alloys. The controlling mechanism of the alloys properties is as an intrinsic effect involving the resistance to shear fracture of cohesive bonding in the alloy. The coefficient of friction generally increase with an increase in solute concentration. Alloys having higher solute concentration produce more transfer to silicon carbide than do alloys having low solute concentrations. The chemical activity of the alloying element is also an important parameter in controlling adhesion and friction of alloys.

—, ANALYTICAL SOLUTION, PLOWING FRICTION COEFFICIENT

35. KOMVOPOULOS (K), SAKA (N) and SUH (N.P.). Plowing friction in dry and lubricated metal sliding. J Tribol Trans ASME. 108, 3; 1986, July; 301-13.

The purpose of the present study is to obtain on analytical solution for the plowing friction coefficient based on a model that represents the plowing process. The dependence of the friction coefficient on such important parameters as the sharpness of the asperities the shape of the plastic zone and the interfacial "friction" conditions is also examined. In addition, experimental evidence for plowing in both dry and lubricated sliding is presented and the range of application of the theoretical model is discussed.

-, ASPERITY CONTACTS, FLASH TEMPERATURE

36. KUHLMANN (Wilsdorf D). Flash temperatures due to friction and joule heat at asperity contacts. Wear. 105, 3; 1985, Oct; 198-98.

Approximate solutions have been obtained for the theoretical flash temperatures at circular and elliptical contract spots between two homogeneous materials when heat is evolved at the interface at a uniform rate, either independent of reocity as in the case of Joule heat or in proportion to the relative speed as in the case friction heat. The parameteres appearing in the corresponding equalation have been expressed in terms of known materials properties plus the number of contact spots and their axis ratio. The accuracy with which the flash temperatures can be known in practice is limited by uncertainty regarding these parameters and by the idealizations embodied in the model. Those theoretical uncertainties are probably no larger than the actual momentary fluctuations in the condition at the contact spots.

—, ASSEMBLIES, RELIABILITY

37. THUM (H). Reliability analysis and service life prediction of friction assemblies. Sov J Frict Wear. 6, 6; 1985, 19-23.

Presents the principle of approach to the analysis of the reliability of friction assemblies. Also examine the possibilities of analysis on the basis of the tribological parameters of the friction assemblies. Service life with the aid of gradual failure models. Lubricates methods by examples of multidisc friction safety clutches and self lubricating sliding bearings.

—, BEARING, SYNTHETIC FIBER BASED

38. ANON. Non-asbestos friction materials. Automot Eng. 94, 4; 1986, Apr. 70-74.

Describes that synthetic-fiber-based, non-asbestos friction products are very popular in the industrial market place due to health and environmental considerarations. They canalso increase wear life and lesser abrasion relative to asbestos bearing products. Many properties and characteristics, including temperature, pressure and speed must be considered when selecting these materials for specific applications. Presents some of the significant friction and wear factors which are helpful when specifying non-asbestos friction materials.

CAPILLARY SYSTEM

39. TENAN (MA), HACKWOOD (S) and BENI (G). Friction in capillary systems. J Appl Phys. 53, 10; 1982, 6687-92.

Develops a new macroscopic one parameter model of static solid liquid friction capillary system. The basic idea is a generalization of the phenomenology of solid friction. The theory considers that the shear frictional force is created by an increase in work of adhesion caused by the deformation of the liquid just before the onset of liquid motion. The theory contains only one parameter, the "frictional angle", characteristics of a given solid surface, and independent of the nature of the liquid. Also derives a functional relationship between friction and equilibrium contact angle.

CONTACT, INCREMENTAL CONSTITUTIVE-RELATION

40. CHENG (JH) and KIKUCHI (NJ). Incremental constitutive relation of unilateral contact friction for large defermation analysis. Appl Mech Trans ASME. 52, 3; 1985, Sept; 639-48.

Presents an incremental constitutive relation of friction contact for large deformation analysis. A model is constructed on the basis of plasticity theory. Extensive studies are laid on how the theory closely stimulates the nature of the friction and how the unknown parameters in the equation are to be determined from the existing experimental results. Discusses possible extentions to allow considerations of temperature and nonlocal effects. Formulations of a quasistatic boundary value problem based on the updated lagrungian approach are summarized. Finite element methods are employed to solve the problem. Examples are given to demonstrate the capacity and adequacy of the proposed model.

EFFECT,,ION PLANTATION

41. HIRANO (M) and MIYAKE ('). Reduction of adhesion by ion implantation. J Tribol Trans ASME. 107, 4; 1984, Oct; 467-71.

Describes the effect of baron and orgon ion implutation on the tribological characteristics of stainless steel. Sliding against a ball were investigated at room temperature using a friction test apparatus. Ball plate geometry can be employing in the absence of a lubricant. Wear performance was estimated using a profilometer tracing of the specimen wear track. Boron ion impluntation reduced both the friction and wear of SUS 440C. The friction coefficient of baron implanted layer decreases with an increase in the total ion dose. Argon impluntation was carried out to distinguish the effects of implunation from the influence of contamination.

ELASTIC LAYER

42. COMNINOU (Mania) and BARBER (JR). Frictional slip between a layer and a substrate due to a periodic tangential surface force. Int J Solids Structure. 19, 6; 1983, 545-39.

Gives a solution for the problem of an elastic layer pressed against an elastic half plane and subjected to a tangential force varying periodicity in time. A leading cycle which initially causes localized slip is followed through unloading and reloading. A limiting load is established below which the steady state of the interface does not involve slop.

ELASTO PLASTIC, DEFORMATIONS

43. KUZMIN (NN). Calculation of friction coefficients with elasto plastic deformation in the real contact of rough surfaces. Sov. J Frict Wear. 6, 5; 1985, 96-101.

Outlines that with the aid of approximate experession for the change of the magnitude of thermal stress along the contact area radius, the forces acting on a rigid spherical identer sliding along or elastoplastic half space are determined the obtained relations are used to calculate the sliding friction coefficient of rough surfaces when there are elastic, elastoplastic and plastic deformations in the real contact zone. Valves of the contour pressure, elastic constant, and roughness parameter are determined for which the friction coefficient has the minimal valve. Experiments conducted on a wide range of contour pressure showed that the computational relations correlate well with the experimental data.

EXPERIMENTAL STUDY

44. ZHANG (Ruiyun). Friction experiment. Int J Mech Eng. Educ. 13, 4; 1985, Oct; 237-41.

Gives a brief note about a set of experiments of friction. The purpose of this experiment is to let the students check Coulomb's friction law, to acquaint them with the methods of measuring the coefficient of static, dynamic and rolling friction and to enable them to understand the causes of friction.

HEAT AND MASS TRANSFER

45. BALAKIN (VA). Heat flow distribution and combined heat mass transfer processes at the contact interface of a friction pair. J Eng Phys. 40, 6; 1981, 660-65.

Analys s the results of experimental studies of heat and mass transfer in the contact zone between two bodies forming a friction couple, using measurements of heat flux directed into one of the bodies.

HOOP APPARATUS

46. WILSDORF (Kuhlmannd), CHANG (YJ), JOHNSON (LB) and BREDELL (LJ). Friction, Wear and interfacial electrical resistance : Part-1. Hopp apparatus. J Tribol Trans ASME. 109, 4; 1987, Oct; 604-08.

Introduces an apparatus for the gathering of data from which a detailed information on the momentorry condition of a sliding interface may be obtained. The information includes the number of the contact spots, the electrical resistivity of the interfacial film, and the flash temperature at the contact spots. The apparatus provides, for the continuous simultaneous recording of the coefficient of friction and of the interfacial electrical resistance of a slide in stick slip motion at constant load and controllable average speed and/or of the interfacial resistance of a slider at constant speed under controlled load. The entire apparatus can be used with a controlled atmosphere or vacuum. The motion of stick slip slider from which the coefficient of friction is inferred, is recorded on one pen of a three pen strip chart recorded, and the electrical contact resistances between the two sliders and the hoop on the other two pens. The dependence of contact resistance on load, obtainable from the fixed slider without remaining the bell jar, permits a determination of the number of contact spots provided the construction resistance is not negligibly small compared to the film resistance. Delibrate changes of the contact spots temperature can be made by adjusting the current through the slider/hoop interfaces.

LIQUID, ROLLING PROCESS

47. MAZUR (VL) and TIMOSHENKO (VI). Rolling process characteristics in the liquid friction regime. [redacted] Sov J Frict Wear, 5 3 1984, 94-102. examines the development of the theory of rolling obtain the solution for conditions when the surfaces of the rolls and the metal being rolled are sparated by a stable lubricant layer. With one use of the

hydrodynamics and plasticity equations the contact stresses, friction coefficient, lubricant layer thickness, and other rolling process parameters are calculated. The influence of the lubricant properties, rolling speed, degree if deformation and forward and backward tensions in examined.

MATERIAL ASBESTOS

48. HUNT (James). Asbestos use arrested in modern friction materials. Eng Materials and Design. 29, 12; 1985, 20-22.

Outlines that arresting movement by the application of friction has been a favored method for many centuries. Today the principle is still the same, but the tendency towards higher speeds, loads and temperatures together with the need for economy and long life, has led to the development of specialized friction materials. Asbestos, when mixed with suitable binders such as resins, has long provided an excellent friction material. It still does, but safety considerations have spaned many non-asbestos products, some of which work better than asbestos itself.

MATHEMATICAL MODEL

49. GEKKER (FR) and RYBALKIN (AG). Experiment planning method in seeking the friction process mathematical model. Sov J Frict Wear. 5, 1; 1984, 77-82.

Describes that a characteristics feature of the operation of friction assemblies such as friction clutches and brakes in the interaction between the dynamic processes and the friction processes. A mathematical model is found using experiment planning theory which adequately describes the friction process. Also describes the experimental technique and presents the result of tests of the materials 143 and 8-45-62 in pairs with Ch Kh D32-52 iron. The mathematical models of the friction processes of these pairs are obtained.

MELT, SQEEZE FILMES

50. STIFFLER (Kent A). Melt friction and pin-on disk devices. J Tribol Trans ASME. 108, 1; 1986, 105-08.

Proposes a melt concept to explain the tribology of unlubricated metal pin-on disk sliding at high speeds. Develops a squeeze film model of the melt film which depends on continually forming melt to give steady state load support. Theories are derived for thefilm thickness, coefficient of friction and wear and apply to pin-on disk data.

MICROPLASTIC DEFORMATION

51. STUPKO (AV) TUCHINSKII (LI) and PADERNO (VN). Mechanicochemical modification of the rubbing surface of aluminum alloys by frictional transfer. Sov Mater Sci. 21, 1; 1985, Jan-Feb; 62-5.

Describes certain structural rules of microplastic deformation of the surface layers of pheno f based self lubricating polymer composite materials and also of V95 aluminum abradents under conditions of loading by friction. The composite materials are practically porosity free and possess a heterogenous structure with clear bounderies, and filers are uniformly distributed in the polymer matrix. The use of composite materials capable in friction of generating lubricants films protecting the aluminum abrodent surface from increased wear and improve the tribotechnical characteristics of aluminum alloys.

NEUTROON IRRADIATION

52. LALJI, MISHRA (R) and BHATTACHARYA (DL). Effect of neutron-irradiation on the internal friction of oxidized silver. Indian J Pure Appl Phys. 20, 5; 1982, 342-45.

Measures the changes of internal friction and rapidity modulus in polycrystalline oxidized silver at different temperatures after neutron-irradiation at room temperature. The main observation is that the grain boundary relaxation peak in depressed and stiffed towards lower temperature side significantly in neutron-irradiated specimen as compared to annealed specimen. This effect is explained on the basis of the model of S.K.Bose etc. according to which the impurity trapped dumb bell interstitials formed near the grain boundaries, relax into favourable orientation on the application of an alternating stress.

OPTIMIZATION, MATHEMATICAL, EXPERIMENT
PLANNING METHOD

53. ERDOKIMOV (Yu A). Optimal solutions in friction and wear problems. Sov J Frict Wear. 5,6; 1984, 25-31.

Presents a technique, regions of application and examples of experimental solution of problems relating to the optimization of friction and wear process with the use of mathematical experiment planning methods. Also presents the technique and examples for the solution of problems relating to experimental optimization of the friction and wear process in the assemblies of machines and mechanisms.

ORGANISATION, DISSIPATIVE STRUCTURE

54. POLYAKOV (AA). Self regulation in friction under selective transfer conditions. J Mech Theor Appl. 3, 6; 1984, 951-63.

Deals with the problem of self organization of the dissipative structure of the selective transfer in friction with allowance for the thermodynamics of non-equilibrium process in open systems provided that this self organization develops on the basis of friction with boundary lubrication. It is shown that under certain conditions in the contact zone in friction the dissipative structure gives rise to a weaker friction and low wear. Also covers the cybernetic interaction between the subsystems, starting with the occurance of feedback and the hierarchy of protective properties and culminating in the mechanism of dissipation of the energy accumulated in the surface layer.

PATTERNS, METHOD, ESTIMATION OF RUNNING IN PROCESS

55. SATO (Hiroki), KYOGOKU (Keiji), CHAO (Sueng-Yi) and NAKAHARA (Tsunamtsu). Estimation of running in process by means of friction patterns. J Jpn Soc Lubr Eng. 31, 2; 1986, 102-09.

Proposes a method for finding out a most suitable running condition. When the bearing conditions during running in were changed stepwise, three patterns were observed successively in unsteady friction variation as the lubricating condition became severer. The running in process was estimable by the use of these patterns. Also demonstrate that the effect of a reduction in the sliding speed was different from that of an increase in the load on running-in. Suggests a method for running-in operation, wherein both the sliding speed and load were altered.

PHYSICOMECHANICAL ASPECT

56. ALEKSEEV (NM) and BUSHE (NA). Some aspects of material compatibility in friction : 1. Subsurface processes. Sov J Frict Wear. 6, 5; 1985, 1-8.

Examines the basic physicomechanical aspects of material compatibility in friction and makes a combined analysis of surface yield and fracture and their influence on friction contact formation and the manifestation of compatibility in friction.

ROLLING RESSISTANCE, MEASUREMENT

57. HALLING (J), SHAFEI (TES) and ARNELL (RD). Rolling resistace of surfaces covered by soft metal films. Proc Inst Mech Eng. Part C. 199, 1; 1985, 51-55.

Measurements have been made of the rolling resistance between steel balls and steel surfaces covéred by soft metal ion-plated films. The results are explained theoretically.

ROUGH SURFACE, FINITE ELEMENT

58. TANGENA (AG) and WIJNHOVEN (PJM). Finite element calculations on the influence of surface roughness on friction. Wear. 103, 4; 1985, June; 345-54.

Two dimensional finite element calculations are used to describe the interaction between a hard rigid asperity and an asperity with an elastic-plastic material behaviour. In the calculations the hard asperity is moved through the soft asperity while the separation of the surfaces is kept constant. The normal and shear forces and the friction coefficient are determined for different separations. Also investigates the influence of adhesive friction in the contact jone and the influence of the radii of the asperities. The finite dlement model in compared with an analytical model.

SELECTION OF LUBRICANTS

59. KOSTETSKII (BI), KARAULOV (AK), KOSTETSKAYA (NB) and ROMANOV (VS). Principles of the selection of materials and lubricants for friction assemblies from energy criteria. Sov Mater Sci. 13, 5; 1977, 556-58.

The overall law governing the change in the parameters of the friction and the wear as a function of the external conditions of the loading is shown in the form of a diagram. Three sectors of friction are distinguished., Sector I corresponds to not fully established conditions of the process in the zone of the friction, and sector III to a transition to nonpermissible damages to the rubbing materials. The study of the range of normal friction and wear (Sector II) is of the most interest. For the course of normal mechanochemical wear, equilibrium between the friction-activation and passivation energies is required. The use of diagrams of the secondary structures enables a directed selection and development of special alloys and lubricating oils for the friction assemblies of machines.

SKIN, NUMERICAL AND EXPERIMENTAL STUDY,
LASER INTERFEROMETER

60. MURPHY (JD) and WESTPHAL (RV). Laser interferometer skin friction meter : a numerical and experimental study. J Phys E. 19, 9; 1986, 744-51.

Deals with establishing the limits of applicability of the simplified theory. Examines two problems. (i) The response of the oil film to a time-varying skin friction such as in encountered inturbulent boundary layers, and (ii) a surface wave instability encountered at high skin friction level. Discusses that the frequency response of the oil film might be such that the indicated skin friction would be mere representative of the low end of the excitation spectrum than of the true average. Also examines stability criteria, leading to the conclusion that the observed surface waves are not the result of a hydrodynamic instability.

SLIDING

61. PAVELESCU (Dau) and TUDOR (Andrei). Sliding friction coefficient : its evolution and usefulness. Wear. 120, 3; 1987, 321-33,

Gives an concise report on the historical development of the term coefficient of friction. Examines the use of the friction coefficient in thermal processes, vacuum, radiation, thin layers, solid lubricants, plastic and ceramic materials and the friction-wear dependence, stick-slip motion and various lubrication regimes (from boundary to elastohydrodynamic). The energy problem is also discussed.

SLIDING, BOUNDARY LUBRICATION

62. KOMVOPOULOS (K). Mechanism of friction in boundary lubrication. J Tribol Trans ASME. 107, 4; 1985, Oct; 452-62.

Investigates the primary friction mechanism between boundary lubricated sliding surfaces. Experiments were performed on well polished aluminium, copper and chromium by using mineral oil lubricant. It was found that the prevailing boundary lubrication model, which is based on the adhesion between asperities and shearing of the lubricant films, can not account for the formations of plowing grooves on polished surfaces.

SLIDING, STICK SLIP MOTION

63. KLAMECKI (Barney E). Catastrophe theory description of stick-slip motion in sliding. Wear. 101, 4; 1985, Feb; 325-32.

Analyses stick slip motion by studying structural changes in the mathematical model describing sliding friction. The sliding system is assumed to operate in a way which minimizes energy input to the system. For an expomential dependence of friction force on sliding velocity, the system sliding behaviour in multivalued for some ranges of values of the system parameters. The effect of different paramater values on system behaviour is illustrated and results are compared with a published steady sliding criterion.

SLIDING, SURFACE, FORCE OSCILLATIONS

64. SOOM (A) and KIM (C). Interfactions between dynamic normal and frictional forces during unlubricated sliding. J Lubr Technol Trans ASME. 105, 2; 1983, Apr. 221-29.

Presents the results of measurements showing large normal and frictional force oscillations during unlubricated smooth sliding between steel surfaces. The measurements were made on a pin-on-disk type apparatus instrumented with piezoelectric force and acceleration transducers. Spectral analysis of the contact forces upto requencies of 2 kHz indicate that the fluctuations have their major components in this frequency range. The force oscillations are primarily associated with normal and tangential contact vibrations which are excited by surface irregularities, being swept through the contact region during sliding.

SLIDING, TRIBOLOGICAL TEXTURE

65. KRAUSE (H) and OECALAN (E). Effect of initial orientation on the formation of tribological texture and on the wear behaviour of the region in the proximity of surface layers under continuous sliding motion in tribological systems. Wear. 108, 4; 1986, 337-43.

The formation and development of a surface crystallographic texture, characteristic of continous sliding motion, is influenced by the initial texture of the triboelements. These changes influence the friction and wear behaviour of the system. An initial texture which promotes the rapid development of a stable final tribological texture results in less deformation of the surface zones.

SQUEEZE FILM EFFECT, INVESTIGATION, STICK SLIP

66. PLINT (AG) and PLINT (MA). New technique for the investigation of stick-slip. Tribol Int. 18, 4; 1985, Aug; 247-49.

Investigates the stick slip phenomenon using an existing high frequency friction machine at very low speed. Static friction was found to vary with frequency and to approach a maximum as the length of time during which the contacting surfaces were at rest increased.

This is due to a squeeze film effect, leading to increasing asperity contact.

STICK SLIP MOTION

67. BO (Li Chun) and PAVELESCU (D). Friction speed relation and its influence on the critical velocity of stick-slip motion. Wear. 82, 3; 1982, Nov. 277-89.

Presents a discontinuous friction model which consists of two exponential functions of the relative speed on the friction model was verified by using the vertical displacement of the sliding body. Also defines three different limiting conditions for the stability of stick-slip motion by using the friction model with various treatments of the approach.

STUDY, ADDITIVES

68. OKABE (Heihachiro), MASUKO (Masabumi) and SAKURAI (Kiyokazu). A Study on boundary friction measurement of boundary friction with additive free mineral oil with flywheel type friction machine. J JSLE Int Ed. 7, 1986, 95-100.

Designs a flywheel type friction machine for precise measurement of boundary friction. The center spindle of the flywheel is supported by two pairs of steel balls at the both ends. Friction at these four contacts is measured by detection of angular deceleration of the fly-wheel. Measurement and calculation are carried out with an electronic computer. Boundry friction is measured under additive free mineral oil lubrication. Boundary friction is mainly controlled by hydrodynamic load supporting ability of the fluid even under the condition of considerable occurence of metal contact.

STUDY, CONTACT AREA

69. CHALLEN (John MO and OXLEY (PLB). Slipline field analysis of the transition from local asperity contact to full contact in metallic sliding friction. Wear. 100, 1-3; 1984, Dec; 171-93.

Describes that under normal well lubricated sliding conditions,the contact is at the tips of asperition and the real area of contact is many time smaller than the apparent area of contact. When the lubrication is poor the normal pressure between the contacting surfaces is very high the real area of contact approaches and in the limit equals the apparent area of contact. The purpose is to investigate the transition between these two oxtremes. The investigation is made using rigid perfectly plastic slip line field theory and concludes with a consideration of how real material properties such as strain hardening might be expected to modify the results obtained.

STUDY, DIFFERENT MATERIALS

70. JABOR (David), Friction the present state of our understanding. J Lubr Technol Trans ASME. 103, 2; 1981, Apr; 169-79.

Presents a general critical picture of the frictional process. Emphasizes the three main elements : the true area of contact, the nature and strength of the interfacial bonds formed at the regions of contact, the way in which the material around the contacting regions is sheared and ruptured during sliding. Deals with metals and reference is also made to ceramics, lamellar solids, polymers and dastomers. Also discusses areas where further progress is desirable.

STUDY, ENERGY BASED MODEL

71. HEILMANN (P) and RIGNEY (DA). Energy based model of friction and its application to coated systems. Wear. 72, 2; 1981, Oct; 195-217.

An energy based friction model is used to develop expressions for the friction coefficient which depend on familiar mechanical parameters, stress- strain curves and microstructural features of the materials. The main assumption is that the frictional work performed is equal to the work of plastic deformation during steady state sliding. Results include the well known expressions for the friction coefficient derieved from adhesion theories. The new model can also be applied to more complex system such as those involving coatings. For soft coatings on hard substrates as well as for have coatings on soft materials, the friction coefficient can be predicted as a functional layer thickness in accordance with observations, guidelines are presented for achieving low friction by using coatings. The new model can also beapplied to systems involving reaction layers, transferred material and solid lubricants of varying thickness.

STUDY, MICROSCOPIC RESISTANCE

72. BERY (GA). Division of frictional Heat : A guide to the nature of sliding contact. J Tribol Trans ASME. 106, 3; 1984, July; 405-15.

Provides a guide to the nature of asperity interactions of the boundary conditions for any subsequent analysis because the division of frictional heat between sliding solids should be sensitive to the interfacial boundary conditions. Investigates theoretically the characteristics of the microscopic thermal resistance at the surface of a sliding solid for several types of asperity interaction. An approximate method has been employed to estimate the thermal resistance of an oxidized surface. The observed division of heat interpreted with reference to thecharacteristic behaviour associated with the various types of asperity interaction. In the wild wear regime oxide films have an effect on the microscopic thermal resistance and on the thermal behaviour of the sliding solids particularly the division of heat between them.

STUDY, OIL GROOVES

73. KRAGEL&SKII (IV), SHCHAVELIN (VM), GITIS (NV) and SARYCHEW (GA). Use of the ocoustic emission method to optimize friction surface micro relief. Sov J Frict Wear. 5, 5; 1984, 1-5.

Studies the effectiveness of the application of oil grooves to friction surfaces to reduce film starvation. The frictional interaction process parameters are determined by analyzing the equals of the acoustic emission generated in the contqct. The acaustic emission signals provide reliable and useful information on the friction conditions on the segments of actual contact.

STUDY, ROLLING

74. KOIZUMI (Todayoshi) and SHIBA ZAKI (Hiroshi). Study of the relationships governing starting rolling friction. Wear. 93, 3; 1984, 289-93.

Investigates the behaviour of the small displacement of starting rolling friction in the rolling contact between a flat surface and rollers. Proposed a rolling friction force displacement relationship in the region of the starting rolling displacement. The area of the hystresis loop increase linearly with the power of the rolling friction. The behaviour of hystresis loop at the rolling contact surface has been investigated experimentally and theoretically. It was found that the area of the hystresis loop increase linearly with the second power of the rolling distance in the region of a starting rolling displacement.

STUDY, SOFT THIN METAL FILM

75. KATO (S), YAMAGUCHI (K), MARUI (E) and TACHI (K). Frictional properties of a surface covered with a soft metal film,1. Experiments on friction between a single protuverance and a surface. J Lubr Technol Trans ASME.

Examines frictional properties in the contact between a hard protuberance and a metal surface covered by a soft thin metal film. The proturberance used in the experiment was a hard steel ball which simulates asperities on many engineering surfaces. The load dependency of the coefficient of friction and the effects of thickness and hardness of the film on the friction are clarified. The simple empirical expression of friction which represent the effect of the film properties, in presented, considering the deformation mechanism of the surface film.

SURFACE MELTING, NUMERICAL MODEL

76. McC. ETTLES (CM). Heat generation and friction in rotating bands. ASLE Trans. 29, 3; 1986, Jul; 312-20.

Describes a numerical model in which it is found that surface melting of the rotating band usually occurs before the system has travelled one band length. Once melting had initiated, it was found limiting the surface temperature to the melting temperature allowed the coefficient of friction to be found as a dependent parameter. The resulting coefficient of friction agree reasonably well with those found experimentally for rotating bands, particularly of residual heat in the tube in allowed for. The discrepency between field tests a laboratory test with pin disk machines in explained on a basis of insufficient size or pressure to achieve local melting.

SURFACE STRESS, COMPUTER MODEL

77. KANNEL (JW). Subsurface stress evaluations under rolling/sliding contacts. J Tribol Trans ASME. 106, 1; 1984, 64-103.

Introduces a computer model for evaluating the sub surface stresses. The model first defining the stress tensor at any point beneath the surface in terms of the surface stresses. The stress tensor are analyzed to determine the maximum shear stresses and stress reversals. As a result of computations with the model, several observations were made. For example the maximum reversing shear stresses are on the plane of the orthogonal shear stress. Further, the magnitude of these stresses is not altered by friction. Under very high friction surface stresses can dominate over surface stresses.

TESTING, ANTIFRICTION MATERIALS

78. PRUZHANSKII (LYu). Campatibility in friction under conditions of lubricant feed termination. Sov J Frict Wear. 6,6; 1985, 71-77.

Introduces a laboratory method for testing antifriction materials to determine their compatibility in friction with tempered steel under conditions of lubricating fluid feed termination. Present results of the use of this method for the example of tests of monolithic Br Azh 9-4 bronze and B83 babbit specimens.

TESTING, BRAKE DYNAMOMETER

79. TSANG (PHS)' JACKO (MG) and RHEE (SK). Comparison of chose and internal brake dynamometer testing of automotive friction materials. Wear. 103, 3; 1985, Jun; 217-32.

Describes that for effective and safe automotive brake system applications, friction material must meet certain minimum requirements for performance noise and durability. To ensure this, friction materials are subjected to a series of vehicle tests on a test track or on the road before they are released as commercial products. While vehicle tests are expensive, time consuming and subject to road conditions and weather varibility, brake dynamometers testing in the laboratory is faster and less costly to screen or verify friction material characteristics.

TESTING MACHINE

80. BRAUN (ED) and SMUSHKOVICH (BL). Modern series produced friction machines. Sov J Frict Wear.

Examines in detail the design characteristics of series produced testing machines for studying friction and wear processes. Also analyzes the causes of experimental errors and ways are shown to eliminate these errors.

TRANSFER, FILM THICKNESS

81. POGOSYAN (AK). Friction transfer film thickness calculation and film effectiveness conditions. Sov J Frict Wear. 5, 2; 1984, 6-12.

Introduces a mathod for calculating the thickness of the transfer film and the conditions of its effectiveness in accordance with the energy model of friction transfer. Calculates the transfer film thickness and the conditions of its cooling during friction of various polymer materials without lubrication.

VISCOUS, ASYMPTOTIC STOPPING

82. TEREKI (I) and KHATVANI (I). On asymptotic stopping in the presence of viscous friction. Appl Math Mech. 46, 1; 1982, 16-21.

Using Lyapunov's second method, sufficient conditions are given for a symptotic stopping in stationary and non-stationary mechanical systems with potential forces in the presence of viscous friction with total dissipation. Results are illustrated by example of a material point moving under the action of gravity over a moving surface, as well as by example of a symmetric gyroscope in a gimbal suspension. Under very general conditions non-stationary mechanical systems are a symptotically stopped in a neighbourhood of a stable equilibrium position under the action of dry friction. It is shown that in the general case viscous friction now does not cause this phenomenon, and sufficient conditions are given for asymptotic stopping.

LUBRICATION, ADDITIVES, ALCOHAL FUELS, DETERGENT

83. LASHKHI (VL), SHOR (GI) and BOREMKO (LV). Features of interaction of alcohal fuels with motor oil detergent additives. Chem Techno Fuel Oils. 21, 11-12; 1985, Nov-Dec; 557-60.

The resources of fuels for internal combustion engines can be expanded by the use of alcohols, alone or in blends with gasoline. However, either the alcohal or the blended fuels may have specific effects on the quality of the motor oils that are used.To a certain degree, this is related to accumulation of low-mole-culor-weight organic acids in the oils, and that are produced by the conversion of alcohols, in particular methanol. The most dangerous of the acids is formic acid. Since detergent additives are used in motor oils to neutralize acidic products, there are more detailed studies of the specific features of the interaction of detergent additives with formic acid.

84. SEMENOV (AP) and NOZHENKOV (MV). On the lubricating action of solid antifriction materials. Sov J Frict Wear. 5, 3; 1984, 16-22.

Explain the action of the atoms and molecules adsorbed by the surfaces and the intercolated atoms and molecules by different nature of adsorption and the different mobility of the adsorbed particles. The minimul friction coefficient is observed in those cases when the adsorbed atoms and molecules are present on the surfaces in the two dimensional gas or liquid state, reducing the interaction of the surfaces participating in sliding and facilitating their mutual displacement. If the number and state of the adsorbed particles are such that solid phase is lets begin to form, the friction coefficient increase. In the case of strong interaction with the surfaces, based on electron collectrization or exchange, the adsorbed atoms or molecules may increase the friction coefficient. Also examine the influence of adsorption on the friction of several lamellor materials and polymers with smooth linear molecules.

ADDITIVES, CHEMICAL SULFIDES

85. MATVEEVSKII (RM) MYULLER (KH) and EVA (AN). Tribological study of oxygen containing sulfides and disulfides. Chem Technol Fuel Oils. 20, 7-8; 1984,. 348-51.

Discusses the efficiency of oxygen containing dialkyl sulfides and dialkyl disulfides as antiwear and extreme pressure additives by the molecular structure. Tribological studies were carried out with the aid of selecting optimal structures for these additives. The limiting lubrication capability, load carrying capacity, of formulation including oxygen-containing, straight chain, symmetrically subsituted dialkyle sulfides and dialkyl disulfides were determined in an Almen-wielanel tester, the antifriction and tribochemical properties were evaluated over a broad range of temperatures on the basis of the oil lubricity as rated by the temperature method.

ADDITIVES, CHEMISTRY

86. KOTVIS (Peter V). Overview of the chemistry of extreme pressure additives. Lubr Eng. 42, 6; 1986, 363-66.

Defines the chemistry involved in extreme pressure (EP) boundary lubrication, especially as it applies to metal working. Examines the molecular structures of the most common EP additives and formulae for the chemical films formed on metal substrates by them. Also examines the relationship between theory and observations. The regorous scienceof metal working appears to depend on surface analytical techniques to further define the phenomenan of EP lubrication.

ADDITIVES, COLD FORGING

87. KOMATSUZAKI (Shigeki). Function of EP additives in lubricants for cold forging. J Jpn Soc Lubr Eng. 31, 6; 1986, 381-86.

Presents a survey of the function of EP agents in lubrication in cold forging. EP agents in oil, If applied properly, can work effectively against welding because of the high adsorptivity and reactivity of the metal surface due to the formation of active nascent surface, exoelectron emission, surface temperature rise caused by sliding and deformation. Some phosporus EP agents produces iron phosphate or iron pyrophosphate on the workpiece during processing. These reaction products exhibit excellent antiwelding performance between workpiece and tools.

-, DETERGENT DISPERSANT

88. INOVE (Kiyoshi). Recent slidies on interfacial properties of detergent dispersant additives. J Jap Soc Lubr Eng. 31, 2; 1986, 71-77.

Modern engine oil formulations usually contains many kinds of additives, such as detergent dispersants, antioxidants, rust inhibitors, antiwear additives and friction modifies. Among these, the detergent dispersant, additives are particularly important for engine oils. Since they constitute about 50% of additives formulations. The performance mechanisms of engine oil additives in a crankcase are very complex. However, this complexity can be overcome by understanding the functions through separating each function at interfaces, e.g. the friction, wear and rust prevention are the phenomena caused at metal/oil interface, the detergency, which involves solubilization, cleansing and acid-neutralization, is those in oils, and the dispersancy is those at solid (sludge, soot and wear particle)/oil interface. In this paper, the recent studies on the interfacial properties, such as micelle formation solubilization adsorption and dispersancy, of detergent dispersant additives are discussed. Also discusses the interactions between engine oil additives in oils and their effects on solubilization, adsorption and wear.

ETHYLENE GLYCOL FLUIDS

89. BUYANOVSKII (IA), SAVITSKII (VYa) and GOROVAYA (T.P.). Tribological studies of Ethylene Glycol fluids. Chem Technol Fuels Oil. 21, 11-12; 1985, Nov-Dec; 622-25.

Experience in the use of water based alcohol-glycerol fluid (WBAGF) in hydraulic systems has shown that they do not completely meet the criteria for antiscoring properties or for maximum economy in production. More promising ethylene glycol fluids (EGF), which can be used over a broad range of temperatures. However, in order to use these materials, effectively, it is necessary to introduce the additives with a high level of antiscoring and antiwear properties.

HIGH ALKALINITY SULFONATE

90. ROMANYUTINA (LV), MISHYNINA (II), ZHURBA (AS) and FIALKOVSKII (RV). Features of synthesis of high alkalinity (over based) sulfonate additives. Chem Technol Fuels Oils. 21, 11-12; 1985, Nov.-Dec; 612, 15.

High-alkalinity calcium sulfonate additives are disperse in systems in which the calcium carbonate and part of the calcium hydroxide (alkaline component) ate stabilized in oils by the sulfonate of the same metal. Investigates the process of incorporation of calcium hydroxide into the additive and determined its optional quantity in the reaction mixture in the corbonation stage, with the airm of obtaining a stable dispersion of the additive with the required total alkalinty.

INTERACTION, SYNERGISTIC EFFECT

91. KAWAMURA (Masuhiko), MORITANI (Hiroshi), ESAKI (Yasuo) and FUJIIA (Kenji). Interaction between sulfur type and phosphorus type EP additives and its effect on lubricating performance. J Jpn Soc Lubr Eng. 30, 9; 1985, 665-70.

A study was made of the intervaction between EP additives, using four sulfur type and four phosphorus type additives with different chemical reactivities to iron and antiwear properties. A synergistic effect was observed with systems of phosphites and sulfur type additives, while no interaction was observed with these of phosphate and sulfur type additives. An EMPA analysis of the wear scars suggestions that phosphites, coexisting with sulfur type additives, behave like phosphates. Thiophosphate was found to be formed in a mixture of phosphite and sulfur type additives and to exhibit a good antiwear property equivalent to that of the synergistic mixture. The chemical reaction between them is also discussed.

KINETIC ASPECTS

92. BATCHELOR (AW) and STACHOWLIAK (GW). Some Kinetic aspects of extreme pressure lubrication. Wear. 108, 2; 1986, March; 185-99.

Studies a theory explaining extreme pressure (EP) lubrication in terms of a short life time surface film. Sulphur and sulphur compounds were devised. In the case of oxygen, diffusion within the oil in thought to be a problem. The superiority of elemental sulphur over oxygen in EP lubrication can be explained by the faster reaction rates with steel. With sulphur compound it was found by experiment that the sulphide film grosth rate is slow and a different model is needed. It is also concluded that EP lubrication films are much thinner than is commonly supposed.

MOLYDENUM CONTAINING DITHIOPHOSPHATES

93. PARFENOVA (VA) and BELOV (PS). Molybdenum containing dithiophosphates as multi functional additives for mineral oils. Chem Technol Fuels Oils. 22, 1-2; 1986, Jan-Feb; 24-26.

Describes multifunctional molybdenum containing additives which are used extensively at the present time. These additives have an antifriction effect under conditions of high loads and temperatures, and are termed 'friction modifiers'. The use of these additives to improve the antifriction properties of motor oils in one of the most effective means for lowering the fuel consumption in internal combustion engines. Among the most promising additives of this type are oil soluble compounds of molybdenum, including molybdenum-containing dithiophesphates. The present work is the study of the functional properties of these additives in a mineral oil.

POLYPHENYLENE SULFIDE, CARGON FIBER
LEMINATE COMPOSITES

94. LHYMN (C). Tribological properties of unidirectional polyphenylene sulfide-carbon fiber laminate composites. Wear. 117, 2; 1987, 147-59.

Investigates the effect of carbon fiber orientation on the friction-wear properties of uniaxial polyphenylene sulfide matrix-carbon fiber composites by means of mechanical wear testing, microscopy and phenomenological models. Explains the experimental findings utilizing a semiempirical wear rate equation and mechanomolecular friction theory.

SERVICE LIFE

95. BADYSHTOVA (K.M.) Prediction of service life of industrial oils with additives. Chem Technol Fuels Oils. 21, 11-12; 1985, Nov-Dec; 599-600.

One of the most important characteristics of oil is the thermooxidative stability. Depending on the operating conditions of a frictional component, the thermooxidative stability of the oil may change substantially with the passage of time. In this connection, sensitive and rapid methods are needed for monitoring oil quality in lubrication systems. The present work has been aimed at determining the feasibility of using thermal analysis to determine the periods for exhaustion of antioxidant additives in oils. The experiments were performed in a setaram analyzer under dynamic conditions, in flow of nitrogen or air.

TRIBOCHEMICAL PROCESS

96. BUYANOVSKII (IA) and KLOSS (JH). Tribochemical process order evaluation based on friction coefficient temperature dependence. Sov J Frict Wear. 6, 3; 1985, 111-14.

Derives theoretically two methods for evaluating the effective order of the tribochemical processes, including the obtaining of the experimental temperature dependences of friction coefficient in oil with chemically active additive in various concentrations. Also evaluating the chemical modification process rate based on the temperature dependence of the friction coefficient, and plotting the obtained quantities in the log-process-rate versus log-additive concentration coordinates. Estimates the process orders by both methods and shows good agreement of the values obtained.

ZINC DIALKYLDITHIOPHOSPHATES,
LUBRICATING OIL

97. BARCROFT (FT) and PARK (D). Interactions on heated metal surfaces between zinc dialkyldithiophosphates and other lubricating oil additives. Wear. 108, 3; 1986, Apr; 213-34.

In oil solution, interactions between zinc dialkyldithiophosphates and heated metal surfaces are strongly influenced by the types of other lubricating oil additives present in the oil. Dispersants of succinimide type lower the extent of film formation by the thiophosphate but-do not appear to change the film composition, whereas metal-containing antirust agents of detergents alter the film composition but not the rate of film formation. The extent of interaction between these additives and the thiophosphate is temperature dependent, concentration dependent and also related to the activity of the thiophosphate additives. The significance of these results is discussed in relation to data obtained in practical tests or formulated oils.

ADHESION,MEASUREMENT

98. TING (Bond-Yen) and WINER (WO) and RAMALINGAM (S). Semi-quantitative method for thin films adhesion measurement. J Tribol Trans ASME. 107, 4; 1985, Oct. 472-77.

A method has been developed for the measurement of adhesion which uses a composite model. A one dimensional elastic analysis is sufficient to determine adhesion stength. In this method an interfacial shear stress is generated at the film to substrate interface by imposing a strain difference between the film and substate. This interfacial shear stress is used to evaluate film adhesion.

ANTIOXIDANTS, IR SPECTROSCOPY, STUDY

99. BISWAS (AK), CHATTARAJ (BD), SURYANARAYANA (I) and RAO (VSB). Evaluations of antioxidants in lubricating oils by differential thermal analysis and IR spectroscopy. Wear. 82, 1-3, 1982, 45-48.

The use of IR Spectroscopy and differential thermal analysis in the study of antioxidants and the assessment of lubricant service life is described.

BEARING, CYLINDRICAL BORE, FINITE ELEMENT METHOD

100. GETHIN (DT). An application of the finite element method to the thermohydrodynamic analysis of a thin film cylindrical bore bearing running at high sliding speed. J Tribol Trans ASME. 109, 2; 1987, April, 283-88.

Presents a finite element model of the thermohydrodynamic behaviour of cylindrical bore bearing. Also compares the predicted behaviour with experimental evidence where possible and favourable correlation is obtained. Includes thermyelastic behaviour in both the shaft and bush. Thi mechanism can influence bearing considerably.

CYLINDRICAL, FERROFLUID

101. SORGE (Francesco). Numerical approach to finite journal bearings lubricated with ferrofluid. J Tribol ASME.

Examines several cases of cylandrical bearings lubricated with ferrofluid by means of a finite difference numerical method. The subregion of caviation is determined by imposing mass conservation across the "rupture" and reformation" boundarics of the complete film. A wide range of bearings lubricated with ferrofluid and characterized by sealing fluid rings which eliminate mechanical means for lubricant supply. The use of these bearings is favourablewhen speeds are low, clearances large, and loads light, because insuch conditions the magaetic effects are comparable with the pure hydrodynamic ones and the load capacity results appreciably higher.

ELASTOHYDRODYNAMIC

102. KARAMI (G), EVANS (HP) and SNIDLE (RW). Elastohydrodynamic lubrication of circumferentially finished rollers having sinusoidal roughness. Proce Inst. Mech Eng. 201, C1; 1987, 29-36.

Describes an isothermal elastohydrodynamic lubfication analysis of rollers having circumferential sinusoidal roughness. Theoretical results shows the influence of roughness amplitude on the distribution of hydrodynamic pressure and film thickness at constant load and constant roughness wavelength. At a large roughness amplitude the hydrodynamic pressure in the valleys between asperity contacts is insignificant and each asperity contact behaves as an isolated elastohydrodynamic point contact. As the roughness is reduced, however, the valley pressures build up, the pressure becomes more uniformly distributed in the axial direction and the minimum film the thickness increases.

ELASTOHYDROSTATIC, CIRCULAR PLATE THRUST

103. SINGH (Chandan), NAILWAL (TS) and SINHA (Prawal). Elastohydrostatic lubrication of circular plate thrust bearing with power law lubricants. J Lubr Technol Trans ASME. 1982, April; 243-47.

Analysis the problem of elastohydrostatic lubrication of circular plate thrust bearings with non-Newtonion power law lubricants. It is seen that the elastic layer on the surface improves the bearing performance for all values of the flow behaviour index n. The load is found to increase for all values of n and the rate of increase of load capacity at a given elastic parameter is higher for higher values of n. The film profile departs from the unloaded shape for an elastic layered surface and the departure is higher for small values of n.

PORUS, GAS LUBRICATED

104. PAL(DK) and MAJUMDAR (BC). Analysis of stiffness and damping characteristics of externally pressurized gas lubricated porous bearings under conical mode of vibration. Wear. 118, 2; 1987, 199-216.

Gives a theoretical analysis of the dynamic behaviour of externally pressurized gas lubricated porous bearings with journal rotation and with regard to the stiffness and damping in the conical mode of vibration. Also investigates the effects of journal speed, feeding parameter, supply pressure, porosity parameter and length to diameter ratio on the stiffness and damping coefficients. A one dimensional flow model without velocity slop is considered.

EXTERNALLY PRESSURISED, POROUS THRUST, STUDY

105. ZAHEERUDDIN (KH) and AYYUBI (SK). Theoretical study of the effects of solid particles in the lubricant of externally pressurized porous thrust bearings. Wear. 89, 1; 1983, 237-44.

Studies the effect of suspended particles (microstructures) in the lubricant of an externally pressurized porous thrust bearing. The expressions determining the pressure distribution and the load capacity are found to be functions of the parameter h/k, i.e. the reciprocal of the ratio of the average radius of gyration k of the microstructures to the film gap h of the bearing, and the parameters characterizing the porous matrix. The presence of microstructures in the lubricant increases the pressure level in the bearing, and consequently the load carrying capacity of a bearing lubricated with a micro polar fluid is greater than that of a similar bearing under similar conditions lubricated with a non micropolar fluid. The load capacity also increases as the parameters characterizing the porous matrix increase.

-, -, POROUS THRUST THERMAL CHARACTERISTICS

106. GORLA (Rama Subba Reddy). Thermal characteristics of a non-Newtonian fluid in a porous thrust bearing. Wear. 67, 3; 1981, 351-59.

Studies the behaviour of an externally pressurized circular porous thrust bearing using a non-Newtonion fluid lubricant. The governing Navier-Stokes equations were reduced to a set of ordinary differential equations and were solved numerically with the cross-flow Reynolds number and the Prandtp number as parameters. Also evaluates the pressure distribution and the lift force. The effects of cross viscosity coefficient on the flow and heat transfer characteristics of the bearing were determined.

-, -, SQUEEZE FILM,THERMAL EFFECT

107. SHUKLA (JB), ISA (M) and ZAHEERUDDIN (KH). Thermal effects in squeeze films and externally pressurized bearings with power law lubricants.Wear. 51, 2; 1978 237-51.

Studies the characteristics of squeeze film and externally pressurized bearings using non-Newtonian power law lubricants where the consistency of the lubricant is varied exponentially with temperature and pressure. Numerical results reveals that the thermal effects can be significant depending upon the parameters characterizing the consistency variations. The flow flux of the lubricant increases or decreases as the flow behaviour index n increases depending upon the choice of the consistency-pressure and consistency-temperature coefficients. The load capacity of the bearings decreases as the parameter characterizing the consistency variations increases.

-, -, VISCOSITY, EFFECT

108. GANJU (KL). Effect of variation of viscosity with pressure and temperature in externally pressurized bearings with variable film thickness. Wear. 54, 1979, 1-6.

Studies the problem of an externally pressurized bearing with converging lubricant film thickness by treating viscosity as a function of pressure and temperature. The load capacity increases with increasing pressure and decreases with increasing temperature. The load capacity of a converging lubricant film is greater than that of a lubricant film of uniform thickness.

HYDRODYNAMIC, FINITE ELEMENT METHODS

109. SONI (SC), SINHASAN (R) and (SINGH (DV). Analysis by the finite element method of hydrodynamid bearing appreciating in the laminar and super laminar regimes. Wear. 84, 1983, 285-98.

By adopting the non linear theory proposed by Elrod and Hg, the generalized Mavier-slokes equations were modified and solved numerically for the flow field in the clerance space of a journal bearing. The performance characteristics of a finite circular hydrodynamic bearing were studied in terms of the Sommerfeld number, attitude angle, oil flow, friction coefficient and temperature rise parameter at various accentricities for Reynold's numbers upto 13300.

HYDRODYNAMIC, NONLINEAR THEORY

110. BANERJEE (Mihir), SHANDIL (RG), KATYAL (SP), DUBE (GS), PAL (TS) and BANERJEE (K). Nonlinear theory for hydrodynamic lubrication. Math And Appl. 117, 1; 1986 48-56.

At moderate Reynolds numbers, for laminor flow of the lubricant, the contribution of the inertia forces to the dynamics of bearings remains small. There are three broad regimes of the bearing operation: a lower regime of laminar flow in which the flow is still laminar but both viscous and inertia forces are significant, and an upper regime in which turbulent conditions prevail. In the narrow inter mediate regime the existing theoretical formulations are applicable for one dimensional in compressible problems only and are not amenable to extensions. To include the inertia effects in an extended Reynolds theory proposes a new iteration process and obtain explicity the inertia contributions to the dynamics of bearings in some particular cases.

—, NUMERICAL MODEL, COMPARATIVE STUDY

111. CHANDRAWAT (H.N.) and SINHASAN (R). Comparison between two numerical techniques for hydrodynamic journal bearing problems. Wear. 119, 1; 1987, 77-87.

Presents a comparison between the two solution techniques i.e. Gauss-Sieldel iterative scheme and the linear complementary problem (LCP) approach. Also presents simple algorithms for the application of the two techniques for solving hydrodynamic lubrication problems. The two techniques are compared through axial groove journal bearings operating in laminar flow regimes. Operations are applied directly on the original fluidity matrices and so no partitioning of these materices and so no partitioning of these materices is required.

INCLINED STEPPED SURFACE, ADDITIVES

112. SINHA(Prawal) and SINGH (Chandan). Effect of additives in the lubricant of a composite bearing with an inclined stepped surface. Wear. 66, 1981, 17-26.

A micropolar fluid, which is characterized by the presence of suspended rigid particles with microstructure, can be used as a model for lubricants containing suspended additive particles. The theory is applied to the study of the lubrication of an inclined stepped composite bearing with an additive containing lubricant. The theory yields results showing an increase in the load carrying capacity and a reduction in the coefficient of friction which are the agreement with experimental absbservations.

INFINITE ECCENTRIC ROTATING CYLINDERS

113. KACOU (A), RAJAGOPAL (KR) and SZERI (AZ). Flow of fluid of the differential type in a journal bearing. J Tribol Trans ASME. 109, 1; 1987, 100-07.

The flow of a homogeneous incompressible non-Newtonian fluid of the differential type between infinite eccentric rotating cylinders is discussed within the context of the lubrication approximation. The problem is studied by means of a perturbation and the effect of the non-Newtonian parameters are delineated.

JOURNAL, ADDITIVES, VISCOSITY VARIATION

114. SINHA (Prawal), SINGH (Chandan) and PRASAD (KR). Effect of viscosity variation due to lubricant additives in journal bearings. Wear. 66, 1981, 175-88.

Micropolar fluid theory, which is possible non-Newtonian model of a suspension of rigid particle additives, is applied to the study of the lubrication of an infinitely long and an infinitesimally short journal bearing. The variation in viscosity along the film thickness is taken into consideration. The prominent features of the presence of solid particles in the lubricant is an increased effective viscosity which increases the load capacity and decreases the coefficient of friction. Whereas viscosity variation tends to decrease both the load and the coefficient of friction for the non-micropolar case, the combined effect is to increase the load and the decrease the coefficient of friction.

-, COEFFICIENT FLUID FILM

115. LUND (JW). Review of the concept of Dynamic coefficient for fluid film journal bearings. J Tribol Trans ASME. 109, 1; 1987, 37-41.

Briefly reviews the development of the concept of spring and damping coefficients for journal bearings. Methods for computing the coefficients are described, and their use in rotor dynamics calculations is discusses. The limitations imposed by non-linearities on the application of the coefficients is illustrated by examples.

-, HYSTERESIS

116. NAKAI (Manabu). A study of hysleresis on attitude-eccentricity loci in journal bearings. J Tribol Trans. ASME. 109, 4; 1987, Oct; 684-90.

Describes hysteresis on attitude-eccentricity loci in journal bearings both theoretically and experimentally. Explains hysteresis by the difference in pressure distributions. Also discusses the changes in the pressure and position of cavities under conditions of increasing and decreasing bearing loads. Also describes the phenomenon of journal shift on the attitude-eccentricity locus. Experimental results are qualitatively releated to the theoretical framework. Some observation are made on the tensil stress in the lubricant as generated in these experiment.

-, MICROPOLAR LUBRICANT

117. ZAHEERUDDIN (KH) and ISA (M). Micropolar fluid lubrication of one dimensional journal bearings. Wear. 50, 1978, 211-20.

Studies the characteristics of infinitely long and infinitely short journal bearings operating with a micropolar lubricant. Study of the characteristics of one dimensional journal bearings shows that the load capacity increases and the coefficient of friction decreases as the parameter $\bar{u}1$ which characterizes the microstructure of the base oil due to the presence of additives, increases. The time of approach increases as the parameter $\bar{u}1$ increase.

-, POROUS, CAVITATION

118. PRAKASH (J) and VIJ (Sanjay Kumar). Axially undefined porous journal bearings considering cavitation. Wear. 22, 1972, 1-14.

An analysis is made of the performance of axially undefined porous journal bearings using the Reynold's boundary conditions. Expressions for angular film extent, pressure distribution, load carrying capacity, attitude angle and coefffficiently of friction are obtained in closed form. The results are shown graphically for situations of practical importance.

-, POROUS, MICROPOLAR FLUID

119. ISA (M) and ZAHEERUDDIN (KH). One dimensional porous journal bearings lubricated with micropolar fluid. Wear. 63, 1980, 257-70.

Analysis one dimensional journal bearinbs lubricated with a micropolar fluid. It was found that the load capacity increased and the coefficient of friction decreased as the micropolar parameter characterizing the concentration of substructures in the lubricant due to the presence of additives increased. As the parameter characterizing porosity increased the load capacity decreased and the coefficient of friction increased.

-, POROUS, NARROW-SQUEEZE FILM

120. MURTI (PRK). Dynamic behaviour of pure squeeze films in narrow porous bearings. J Lubr Technol Trans ASME.

Analyses the dynamic behaviour of squeeze film in narrow porous journal bearing under a cyclic load. a thin-walled bearing with a nonrotating journal is considered and a closed form expression for the pressure distribution is derived. The locus of the journal center is found by numerical methods and it is established with an example avoided by approoriate design of the bearing. Consequently, it is proved that pure squeeze films have a load capacity only under cyclic loads. The analysis also reveals that the permeability of the bearing material and the wall thickness of the bearing influence significantly the operating eccentricity ration.

-, -, -, -, MICROPOLAR FLUID

121. ZAHEERUDDIN (KH). Squeeze film narrow porous journal bearings lubricated with a micropolar fluid. Wear. 64, 1980, 163-74.

Investigates the squeeze film behaviour of a narrow porous journal bearing operating with a lubricant containing solid particle additives, i.e. a micropolar fluid. One dimensional journal bearings operating with a micropolar lubricant have been analysed. It has been shown that the load capacity increases and the coefficient of frictions decreases with the concentrations of the microstructures. Also investigates the characteristics of a micropolar lubricant is a squeeze film porous spherical bearing.

-, -, SQUEEZE FILM

122. ISA (M) and ZAHEERUDDIN (KH). Characteristics of squeeze film porous journal bearings with micropolar lubricant. Transactions of the CSME . 6, 3; 1980-81, 146-50.

In this paper, the characteristics of squeeze film two dimensional porous journal bearing with micropolar lubricant have been analysed. The generalised form of Darcy's law governing the flow of micropolar fluid in a porous channel has been derived. The generalized Reynold's equation for a micropolar fluid lubricated squeeze film porous journal bearing is also obtained. It is shown that the load capacity and the squeezing time are higher with a micropolor fluid than with a Newtonian fluid.

123. ZAHEERUDDIN (KH). The dynamic behaviour of squeez film in one-dimensional porous journal bearings lubricated by a micropolar fluid. Wear. 71, 1981, 139-52.

The generalized Reynolds equation governing the pressure distribution for a micropolar lubricant in a dynamically loaded porous journal bearing is derived and applied to one dimensional squeeze film journal bearings operating under a cyclic load. The analysis indicates how the microstructure in the lubricant, the permeability of the bearing material and the bearing wall thickness influence the operating eccentricity ratio.

-,-, TANGENTIAL VELOCITY

124. CHATTOPADHYAY (Ajit Kumar), MAJUMDAR (BC), and RAO (NS). Stability of a rigid rotor in finite externally pressurized oil journal bearings with slip. J Tribol Trans ASME. 109, 2; 1987, April; 301-305.

Deals with a study of stability characteristics of externally pressurized porous oil journal bearings of finite length considering the tangential velocity slip at the bearing film interface. Also considers the translatory and rotating components of journal vibration for that purpose. Describes stability curves that have been drawn for different slip parameters, accentricity ratios, slenderness ratios, bearing speed parameters etc.

MAGNETOHYDRODYNAMIC, POROUS THRUST,
INERTIA EFFECT

125. ZAHEERUDDIN (KH). Inertia effects in magnetohydrodynamic porous conducting thrust bearings. Wear. 67, 1981, 99-106.

Studies the effect of fluid inertia in an externally pressurized porous thrust bearing in the presence of a uniformly applied transverse magnetic field. The load capacity increases and the flow flux decreases as the fluid inertia term, the applied magnetic field or the conductivity of the plate increases. Both the load capacity and the flow flux increase with increasing permeability of the plate.

MICROPOLAR FLUID, SQUEEZE FILM

126. ISA (M) and ZAHEERUDDIN (KH). Analysis of step bearings with a micropoaer lubricant. Wear. 47, 1978, 21-29.

Analysis the characteristics of squeeze film parallel and circular step bearings using a micropolar fluid as the lubricant. It was found that the load capacities increase as the micropolar parameter $\bar{u}_1$ increases or as $M = h^2\mu / 4\gamma$ decreases. The load capacity also decreases as the step height increases.

MICROPOLAR LUBRICANT, HYDROSTATIC STEP SEALS AND CONICAL BEARINGS

127. ISA (MA) and ZAHEERUDDIN (KH). Hydrostatic step seal and externally pressurized conical step bearing with micropolar lubricant. Jpn J Appl Physc. 16, 9; 1977, 1577-82.

Studies the characteristics of micropolar fluid as lubricants, in hydrostatic step seals and conical bearings. The load capacities of the bearings increase with the increase in the step hights. It has also been shown that the load capacities increase as the micro-polar parameter $\bar{u}_1$ increases or as M_2 decreases.

ROLLING, ANALYSIS, STRESSES

128. IOANNIDES (E) and KUIJPERS (JC). Elastic stresses below asperities in lubricated contacts. J Tribol Trans ASME.

The pressence of contacting asperities in lubricated rolling bearings modifies the subsurface stress field strongly in the neighbourhood of the surface and to a lesser extent at larger depths where the maximum of the shear or Von Mises stress of a x smooth Hertizian contact normally exist. The near surface stresses are of importance because they may result in micropitting, a mode of surface stress which leads to the eventual fatique failure of the contacting surfaces. Presents a mathematical model which allows the statistical calculation of important parameters of the stress field generated under elastically deforming asperities during their passage through a lubricated contact.

ROLLING ELEMENT, SOLID LUBRICANTS

129. KANNEL (JW) and MERRIMAN (TL). The effect of solid lubricants on the stability of rolling element bearings. J Tribol Trans ASME. 109, 2; 1987, April; 351-55.

A technique has been developed for modeling solid films in rolling element bearings. An effective viscosity can be calculated for a solid film as a function of film shear modulus and ball race friction coefficient. The calculated effective viscosity can subsequently be used as an input to a numerical model of cage motion and stability. Results from a sample calculation of effective viscosity and prodiction of cage stability for a turbo pump bearings are preseuted for flows of molybdenum disulfide and polytetra fluoroethylene.

SECTOR SHAPED THURST, DESIGN

130. SINGH (AP). Overall optimum design of a sector-shaped thrust bearing with continuous circumferential surface profiles. Wear. 117, 1; 1987, 49-77.

Investigates the effect of continuous circumferential surface profiles on the performance characteristics of a sector type thrust bearing. Reynolds equation in polar form for two-dimension lubricant flow has been solved by using a computer-aided finite difference method. Pressure distributions are used to evaluate the location of center of pressure, load carrying capacity, flow rate, side leakage frictional power loss, coefficient of friction and the temperature rise. Also investigates the optimum values of pad inclunation capacity design requirements such as maximum load carrying capacity and minimum coefficient of friction for all the fluid film shapes. Defines performance characteristics in a non-dimensional coefficient form and presents as a function of the aspect ratio of the pad. Result are presented in the form of design charts. Also discusses an overall optimum design procedure to accomplish maximum load-carrying capacity along with minimum coefficient of friction and an optimum number of pads. Includes a numerical example to demonstrate the complete optimum design procedure and application of the design charts.

S H O R T

131. BUCKHOLZ 'RH) and HWANG (B). Accuracy of short bearing theory for Newtonian lubricants. J Tribol Trans ASME. 108, 1; 1986, 73-9.

Studies the accuracy of the short bearing approximation. Results apply to Newtonian lubricants and non-Newtonian power law lubricants. Small aspect of ratio formula is used for accurately predicling the bearing pressure and the loads for a practical range of aspect ratio and eccentricity ratio.

SLIDER, INERTIA EFFECT

132. BUCKHOLZ (RH). The effect of lubricant inertia near the leading edge of a plane slider bearing. J Tribol Trans ASME. 109, 1; 1987, 60-64.

Describes that the primery effect of fluid inertia to raise the pressure boundary condition near the bearing leading edge. Lubrication theory is used to determine the pressure in the fluid film in the region downstream of the bearing entry. The leading-edge pressure increase caused by convective inertia is determined by a mass-flux balance between the flow near the leading edge, and the flow through the bearing gap, which is determined by lubrication theory. Analytical results are obtained both for the convective inertia pressure at the bearing entrance and for the pressure under the slider bearing. Results are compared to other numerical calculations and to analytical results, where the fluid inertia terms were kept throughout the bearing gap.

SOLID SLIDER

133. BERETTA (Gian Paolo), NIRO (Alfonso) and SILVESTRI (Mario). Solid slider bearings lubricated by their own melting or sublimation. J Tribol Trans ASME. 109, 2; 1987. Apr; 296-300.

Studies the hydrodynamic lubrication of solid sliding bearing with spontaneous fusion or sublimation of the solid slider substance. Lubrication is sustained by the fluid film produced by fusion or sublimation. Emphasis is on liquid film lubrication of a melting solid slider and gaseous film lubrication of a sublimating every parameter of the problem, together with conditions specifying the range of validity, and conditions guaranteeing that fusion sublimation develop the necessary supply of lubricant.

TILTING PAG, STIFFNESS AND DAMPING PROPERTIES

134. LUND (Jorden W) and PEDERSEN (Lars Bo). Influence of pag flexibility on the dynamic coefficients of a tilting pag journal bearing. J Tribol Trans ASME. 109, 1; 1987, 65-70.

An approximate method is developed to include the flexibility of the pad in the calculation of the stiffness and damping properties of tilting pag journal bearing. It is a small-amptitude perturbation solution in which the pad deformation is accounted for solely by the change in clearance. A comparison of results with those obtained from a more complete elastohydrodynamic solution shows good agreement.

BOUNDARY, SURFACE FILMS

135. JONES (William R) and ISHIGAKI (Hiroyuki). Boundary lubrication from new view point. J Jpn Soc Lubr Eng. 31, 3; 1986, 157-62.

Presents a review on the various lubrication regimes, withparticular emphasis on boundary lubrication. The types of wear debris and the extent of surface damage are shown for each regime. Also discusses the role of boundary surface films along with their modes of formation and important physical properties. Also considers the effects of various operating parameters on the friction and wear in the boundary lubrication regime.

CONTACTS, ELASTOHYDRODYNAMIC

136. HOUPER (LG) and HAMROCK(BJ). Fast approach for calculating film thickness and pressures in elastohydrodynamically lubricated contacts at high loads. J Tribol Trans ASME. 108, 3; 1986, Jul; 394-402.

CO-ROTATIONAL JEFFREYS FLUID MODEL

137. RAJALINGHAM (C) and PRABHU (BS). Hydrodynamic lubrication using co-rotational Jeffreys fluid model. Into J Mech Sc. 28, 5; 1986, 289-94.

Theoretically investigates the performance of a non-Newtonian lubricant in hydrodynamic lubrication using a co-rotational Jeffreys fluid model. The normal stress effect has no appreciable influence in hydrodynamic lubrication due to the bounded variations of the normal stress components with shear rate in simple shear flow. In hydrodynamic lubrication applications the above lubricant model degenerates into an inelastico-viscous lubricant model.

CYLINDICAL BORE BEARING, FINITE ELEMENT METHOD

138. MEDWELL (JO), GETHIN (DT) and TAYLOR (C). A finite element analysis of navier stokes equations applied to high speed thin film lubrication. J Tribol Trans ASME. 109, 1987, 71-76.

The performance of a cylindrical element method bore bearing fed by two axial grooves orthogonal to the load line is analyzed by solving the navier stokes equations using the finite element method. Gives detailed information about the the three dimensional velocity and pressure field within the hydrodynamic field. It is also shown that the method may be applied to long bearing geometries where recirculatory flows occur and in which the governing equations are elliptic. This analysis confirms that lubricant inertia does not effect bearing performance significantly.

CYLINDER, SLIDING, ELASTOMERIC LAYER

139. HOOKE (CJ). Elastohydrodynamic lubrication of a cylinder on an elastomeric layer. Wear, I11, 1; 1986, Aug; 83-99.

Examines the lubrication of a rigid cylinder sliding or rolling on an elastomeric layer which is bonded to a rigid substrate. Also presents the results for central and minimum film thicknesses for the complete range of operating conditions and for a wide range of values of the ration of the semicontact-width-to layer thickness.

DETERMINATION, FILM THICKNESS

140. SUN (DC), CHEN (KK), and NINE (HD). Hydrodynamic lubrication in hemispherical punch stretch forming : modified theory and experimental validation. International Journal of Mechanical Sciences, 29, 10/11; 1987, 761-76.

Discusses a hydrodynamic theory of punch stretch forming. Gives refined calculations of the lubricant film thickness, the hydrodynamic friction and the strains in the sheet metal. Several sheets materials and liquid lubricants are tested with the use of a punch stretch apparatus, and the strains in the sheet metal are measured. The comparison between the cauculated and measured strain, distributions confirms the velidity of the refined lubrication model, which identifies a dimensionless parameter that characterizes the state of lubrication at the punch sheet interface.

EFFECTIVENESS, TESTING

141. REIFF(RP). Rail/wheel lubrication studies at fast. Lubr Eng. 42, 6; 1986, Jun; 340-49.

Discusses the effects of lubrication at the railroad car wheel and rail interface. Proper control of lubrication has been shown to be a powerful agent in reduction of rail guage face and wheel flange wear. Fuel savings are also possible throughs lubrication of curved and tangent track. A lubrication study was conducted in 1983-84 at the Facility for Accelerated Service Testing (FAST) to develop methods of measuring lubrication effectiveness. Briefly reviews that study and provides a ranked of grease types according to their performance at FAST.

ELASTOHYDRODYNAMIC

142. WANG (SH), ZHANG (HH) and HUA (DY). Influence of the viscoplastic and viscoelastic character of a lubricant on elastohydrodynamic lubrication. Wear. 118, 2; 185-97.

Discusses the non-Newtonian constitutive equation proposed by Johnson and Winer. Presents the lubrication equations suitable for the viscoplastic rheological model and the viscoelastic model. Full numerical elastohydrodynamic lubrication solutions for the viscoplastic model and the viscoelastic model are obtained in order to observe the effects of the elastic shear modulus of the fluid and limiting shear stress on the pressure distribution, film thickness and coefficient of friction.

ELASTOHYDRODYNAMIC, REYNOLDS-EYRING EQUATION

143. CONRY (TF), WANG (S) and CUSANO (C). A Reynolds Eyring equations for elastohydrodynamic lubrication in the contacts. J Tribol Trans ASME. 109, 4; 1987, Oct; 648-58.

Deals with a new Reynolds equation which is derived for flow in one dimension. It is based on the Erying theory of non-Newtonian flow. Investigates that this new equation reduces to the traditional Reynolds equation as the Eyring model approaches the Newtonian model in the limit. Also presents a numerical solution for a selected oil at two different temperatures. The central film thickness decreases with increasing dimensionelss viscosity parameter and slide/roll ratios. A transition zone is noted through which the ratio of minimum to central film thickness passes as the pressure distribution goes from near Hertzian to a distributinn that deviates from Heartzian.

—, HEARTZIAN CONTACT

144. HOOKE (CJ). Note on the elastohydrodynamic lubrication of soft contacts. Proc Inst Mech Eng Part C. 250, C3; 1986, 189-194.

The clearances in highly loaded non-Hertzian contacts can be calculated directly from the dry contact pressure distribution. This note presents a method of extending the analysis into loss highly loaded regions. This method accurately predicts the clearance over much of the transition zone for Hertzian contacts and its use in a non Hertzian situation is illustrated using the contact between a rigid cylinder and an elastomer-lined surface as an example.

EROSION, IMPACTOR SYSTEM

145. DEVASWITHIN (A) KRISHNAN (B) and PITCHUMANI (B). Prediction of particle degradation during impact on a flat surface. Wear. 118, 3; 1987, 281-89.

Studies an impactor system which indicates that the size and shape both play an important role in erosion. A simple apparatus is used to determine experimentally the particle size degradation for various inpinging velocity at various number of impacts. A communication model is used with slight modividations. Results shows that the model representation is adequate for the prediction of attried product size distribution.

EXOACTIVE SURFACE

146. KOICHI (NAKAJIMA). Surface science and technology in lubrication engineering. J Jpn Soc Lubr Eng. 31, 6; 1986, 363-64.

Briefly describes contribution of surface science and technology to lubrication engineering. Degradation of mechanical properties of metals due to the absorption of surface active additives-Rebbinder effect, strengthening of the mechanical properties due to the formation of the thin oxide film on the surface, Roscoe effect and the emission of electrons from an exoactive surface, Kramer effect are discussed in relation to the tribochemical reaction occuring during friction and wear of materials. It is emphasize that the nature of the exoactive surface has a great effect on the mechanism of lubrication.

EXTRACTION REPLICA, METHOD

147. IVES (LewisK). Extraction Replica method for the study of surface films. ASLE Trans. 28, 1;, 1985,87-90.

Describes an extraction reptica method by means of which thin solid films on worn surfaces may be removed from sel-cted areas for examination in the transmission electron microscope. A scratch or several scratches are made on the worn surface with pointed stylus. Displaced or lossened fragments of material are removed by means of a plastic extraction replica. After subsequent processing of the replica, sufficiently thin fragments can then be examine by transmission electron microscopy, electron diffraction and the allied methods of X-ray energy dispersive analysis and electron energy loss spectroscopy. Examples are given to illustrate the application of the scratch extraction replica method.

FILTERATION

148. TICHY (John A). Modelt for optimum filtration of a lubrication system. Wear, 111, 1; 1986, Aub; 73-82.

Proposes a steady state model for the filtration of a simple lubrication system consisting of an engine and filter. It is shown that the optimum filter, an economic sense is one that filters all particles above a particular 'cut off' size and non below that size. Real filters do not behave in this way. Rather, with increasing particle size an increasing fraction of particles is captured. The cut of size is defermined, in principle, from a series of field tests. A recent filtration theory is used to suggest a method to design a filler which most nearly approaches the optimum filler.

FLUID INERTIA, FINITE SQUEEZE FILM DAMPER

149. TICHY (JA). A study of effect of fluid inertia and end leakage in the finite squeeze film damper. J Tribol Trans ASME. 109, 1; 1987.

Presents an analytical solution to the problem of the finite length squeeze film damper performing a circular centered orbit, including the effect of fluid inertia and end leakage. The solution in based on the classical separation of variables method. It would only be practical using the digital computer library to find eigenvalues and eigenfunctions of the resulting ordinary differential equation. More physically understanding is obtained and extensive parametric studies are possible at negligible cost.

HARD LAYERS, TIN COATING

150. KOMOVPOULOS (K), SAKA (N) SUH (N.P.). The role of hard layers in lubricated and dry sliding. J Tribol ASME. 109, 2; 1987, April, 223-31.

Deals with the lubricated and dry experiments on titanium and steel surfaces with an without Tin sputtered coating of various thicknesses. Critically examine the significance of the layer thickness, interfacial "friction" magnitudes of normal and tangential surface tractions, and the mechanical properties of the layer and of the substrate. Also examine the conditions under which the deformation mode at the solid-solid contacts is elastic or plastic are addressed in light of the experimental evidence and a finite element analysis. Investigates that surfaces with very low friction, especially for unlubricated sliding, and practically zero wear rates can be obtained in both lubricated and dry sliding by coating the surfaces with sufficiently thick. Tin layers. Removal of the protective Tin layer resulted in plowing, severe damage, and delamination.

HYDRODYNAMIC, MICROPOLARITY ROUGHNESS

151. PRAKASH (J), TONDER (K) and CHRISTENSEN (H). Micropolarity roughness interaction in hydrodynamic lubrication. Journal of Lubrication Technology Trans ASME. 102, 180, July; 368-73.

Describes a theoretical analysis of micropolarity roughness interaction. A modified Reynolds' type equation for a rough surface based on micropolar fluid theory is developed and is applied to the case of a fixed inclined slider, having a one dimensional roughness patterns in the direction transverse to sliding. The analysis shows that the inclusion of surface roughness in the theory causes an increase in the pressure level, over and above the micropolar level. These additional increases are of a smaller order and are not likely to mask the increases caused by additives and surface forces (characterized by micropolarity) as in conjectured by some earlier workers.

-, STOKES ROUGHNESS, COMPARATIVE STUDY

152. MITSUYA (Y) and FUKUI (S). Stokes roughness effects on Hydrodynamic lubrication : Part 1. Comparison between incompressible and compressible lubrication films. J Tribol Trans ASME. 108, 2; 1986, Apr; 151.

Presents a perturbation method for the navier stokes equations to analyze stokes roughness effects on hydrodynamic lubrication in both incompressible and compressible films. The solution is obtained from direct numerical calculation by using an actual rough spacing without applying the currently accepted assumption that the roughness height should be small.

-,-, SLIP FLOW

153. MITSUYA (Y) and FUKUI (S). Stokes roughness effects on hydrodynamic lubrication : Pt. II. effects under slip flow boundary conditions. J Tribol Trans ASME. 108, 2; 1986, Apr; 166.

Studies stokes roughness effects on hydrodynamic lubrication in the slip flow regime. Slip flow boundary conditions for Navier stokes equations are derived, assumingthat the fluid on a surface slip due to the molecular mean free path along the surface, even if the surface is rough. The perturbation method for Navier stokes equations is then applied. Slip flow effects on load carrying capacity and frictional force are numerically clarified for both stokes and Reynolds roughness.

-, THEORY

154. BURGVITS (AG). Works of NP Petrov and the hydrodynamic theory of lubrication. S J Frict Wear. 5, 3; 1984, 118-122.

The work 'friction in Machines and the influence of lubrication by fomous Russian scientist and engineer N.P. Petrov was the foundation on which the modern hydrodynamic theory of lubrication in machines was constructed. All of Petrov's very important constructions on the physical nature of the friction process of lubricated machine parts have been universally accpted and his formula for determining the friction on a journal is one of the basic formulas in tribology.

155. PINKUS (Oscar). The Reynolds Centennial : a brief history of the theory of hydrodynamic lubrication. J Tribol Trans ASME. 109, 1; 1987, 2-20.

Reviews the brief history of the theory of hydrodynamic lubrication. Discusses the topography of the subject as it was formed and shaped by key contributors in the course of its development. The clapsed century is divided into five periods characterised by their unequal progress in the field. An attmpt is made to to evaluate the present status of the theory vis-a-vis the past. Aim is to help the present community of the tribologist to properly chart their professional activities for the future.

-,-, ASYMPTOTIC AND QUALITATIVE STUDY

156. KUDISH (II). Aymplotic and qualitative study of plane problems of contact-Hydrodynamic lubrication theory for severe loading regimes. Sov J Frict Wear. 6, 1; 1985, 68-76.

Makes an symptotic and qualitative study of plane stationary isothermal and nonisothermal contact hydrodynamic problems for rough elastic bodies, separated by a thin layer of in compressible liquid lubricant with Reiner-Rivlin rheology. Microasperity crushing is approximated by a power-law pressure function. Describes approximate and incomplete asymptotic methods for studying the subject problems. Gives a general characterisation and note some pecularities of the behaviour of the problem solution under severe loading conditions. Also presents several numerical results.

INERTIA EFFECT

157. YOU (HI) and LU (SS). Inertia effect in hydrodynamic lubrication with film rupture. J Tribol Trans ASME. 109, 1; 1987, 86-90.

Investigates the fluid inertia effect on the pressure distribution in convergent-divergent bearing using different Cavitation algorithm. The modified Reynolds equation is solved analytically for infinitely long bearings including the cylinder-plane bearing and the journal bearing. The fluid inertia tends to stretch the fluid film old to move the film rupture point further downstream. The effects are profound even at a moderate value of the Reynolds number.

-, SQUEEZE FILM

158. ZAHEERUDDIN (KH) and AYYUBI (SK). Inertia effects in squeeze film between two circular plates with power law lubricants. In : National Conference on Industrial Tribology. (Hyderabad). 1984.

Analysis the pressure and inertia effects in squeeze film between two circular plates lubricated with non-Newtonian power law fluid. The load capacity of the bearing increases as the inertia term or the pressure-consistency coefficient increases. The squeezing time also increases as the pressure consistency index increases for fixed load capacity and decreases as the consistency index increases.

INTERFACE TEMPERATURE, SURFACE TOPOGRAPHY

159. BHUSHAN (B). Magnetic Head-Media interface temperatures. Part 1 : Analysis. J Tribol Trans ASME. 109, 2; 1987, April; 243-51.

Describes as "generalized" thermal analysis to estimate the flash temperature during sliding when both surfaces are of more or less equal roughness or one surface is substantially smoother than the other. Consider high and low speed cases. The basic model includes surface topography statistics, frictional conditions, and mechanical and thermal parameters. Also calculated temperature history during the life of an individual asperity contact from which average temperatures of an asperity contact are calculated. Also considers thermal interaction of neighboring asperity contacts. Presents an analysis to show how individual asperity temperatures should be averaged. Also analysed temperature variations perpendicular to the sliding surfaces. Closed-form equations are developed throughout the analysis, which can be used in the design of any sliding interface.

MAINTENANCE, DESIGN, PARAMETER

160. MEEK (Gray R). Design parameters for a lubrication maintenance facility. Plumbing Eng. 14, 6; 1986, 25-84.

When designing a high pressure product supply system several factors have to be considered prior to sizing product lines and choosing equipment. High pressure product supply systems for maintenance facilities are made up of the following : The product to be distributed, storage for the product, pumping equipment, the type of vehicles and site. Product lines from the pump to the dispensing point, air-system, hose, reel, product supply hose, or tapper bar, product dispensing valve either metered or non-metered, other equipment and accessories. These are necessary to achieve a working system.

NON-NEWTONIAN, HYDRODYNAMIC, PLAIN STRAIN FORGING PROCESS

161. SURENDER KUMAR, UMESH CHANDRA and BALASUBRAMANIAN (TV). An analysis of non-Newtonian hydrodynamic lubrication in the plain strain forging process. Wear. 71, 1981, 293-305.

Lubrication is of vital importance in a number of forging operations because good lubrication leads to an improved product quality through the reduction in the number of defects and the improvement in the dimensional accuracy and surface, finish, While studying lubrication process of plain strain forging, investigates have assumed that the lubricant behaviour was newtonian, however, the modern lubricants contains additives which cause them to behave in a non-newtonian manner. In the present the lubrication process of plain strain forging with flat dies was studies assuming that the lubricant behaved as an incompressible power law fluid. A more fundamental understanding regarding the interactions of the non-newtonian properties of the lubricant with other physical parameters has been achieved.

—, THERMAL CHARACTER

162. WANG (SH) and ZHANG (HH). Combined effects of thermal and non-newtonian character of lubricant on pressure, film, profile, temperature rise, and shear stress in EHL. J Tribol Trans ASME. 109, 4; 1987, Oct; 666-70.

Presents a thermal non-Newtonian analysis of pressure, film, profile, temperature rise and shear stress in line contact. Also presents a lubrication equation for nonlinear rheological model. Full numerical solutions coupling the lubrication equation with film shape equatio and energy equation are obtained. Reveal the combined influence of thermal and non-Newtonian character of lubricant on elasto-hydrodynamic lubrication. Results shows that the minimum film thickness is influenced slightly. Nevertheless, the spikes of pressure and temperature rise, and the coefficient of friction are strongly affected by the rheological character of lubricant. Concludes that both the temperature rise and non-Newtonian character of the oil film should be considered in EHL analysis in order to obtain reliable results.

OSBORN REYNOLD THEORY

163. SZERI (AZ). Some extensions of the lubrication theory of Osborne Reynolds. J Tribol Trans ASME. 109, 1; 1987, 21-36.

Outlines some of the most important extensions of the lubrication theory of Osborn Reynolds. The material is neither complete nor particularly up-to-date. Some of the most important names in tribology are not mentioned. A number of significant development are also left out.

PERFORMANCE, EVALUATION

164. BRUCE (Robert W). High temperature tribo-test for lubricated contacts of aluminum against steel. Lubr Eng. 41, 7; 1985, Jul; 430-33.

A test was developed for evaluation of tribological contacts using viscous and solid lubricant over a wide range of temperatures and speeds. With contacts of aluminum against steel, initial test result consisted of measurement values of friction as well as pickup of aluminum adhering to the steel surface. The influence of surface roughness patterns and alloys may also be studied with the chosen test configuration of face loaded cylinders.

POLYNOMIAL MODELS

165. SARKAR (P), CHOWDHURY (B) and MUKHERJEA (RN). Generalized polynomial models for non-linear resistance versus flow problems. J Inst Eng India Part. 61, 3; 1981, 67-70.

Non-Newtonian viscosity and sliding friction coefficient are fitted with shear rate and sliding velocity for several viscous and mechanical systems respectively. The model are non-linear polynomials of two classes one having an intercept on the dependent variable axis, the other without such an intercept. An attempt is made to generalize the suitability of such polynomial models relating potential and flow or resistance and flow variables for first order systems. A mechanical analog for non-Newtonian fluids is proposed, which is actually a modification of the classical desh pot.

REYNOLDS THEORY

166. SHAD IRO (Wilbur). Impact of Reynolds theory on bearing and seal design. J Tribol Trans ASME. 109, 1; 1987, 92-49.

Concentrates on some of the developments for solving the Reynold's equation. The aim is to demonstrate by application example some of the advances made in technology due to the development of Reynold's theory. Solving the equation has produced tremendous advances in bearing design and development and insight into the mechanisms of lubricating film behaviour. Concentrates on some applications that have followed a better understanding of fluid film phenomena.

RHEOLOGY, STUDY

167. RAMESH (KT) and CLIFTON (RJ). A pressure-shear plate impact experiment for studying the Rheology of lubricants at high pressure and high shearing rates. Journals of Tribology Trans ASME. 109, 2; 1987, April; 215-22.

Describes a new plate impact configuration for subjecting lubrications to simple shearing motion under uniform hydrostatic pressure. Thin layers of the lubricant are confined between two hard metallic plates which are subjected to impact by a paralled plate that is inclined relative to the direction of approach in order to induce both pressure and shear loading. Stress waves in the hard plates are monitered by laser interferometry and all measurements are made before unloading waves arrive from the periphery. For approximately one micro second the compressed lubricant is subjected to a simple shearing motion and a continuous record of the shear stress andshear rate is obtained.

ROLLERS, THERMAL AND SQUEEZING EFFECT

168. PRASAD (Dhaneshwar), SINGH (Punyatma) and SINHA (PRAWAL). Thermal and squeezing effects in non-Newtonian fluid film lubrication of rollers. Wear. 119, 2; 1987, 175-90.

Deals with the problem of two inelastic heavily loaded rollers, with rolling and squeezing motions lubricated by a non-Newtonian power law fluid under cavitation conditions. The lubricant consistency is assumed to vary exponentially with pressure and temperature which are computed numerically be solving, simultaneously, modified Reynolds and energy equations. Presents and discusses various bearing characteristics. Also presents the results obtained when the temperature effect on the lubricant consistency in neglected.

ROLLING CONTACT, CAVITATION

169. SINHA (Prawal) and SINGH (Chandan). Lubrication of a cylinder on a plane with a non-Newtonian fluid considering cavitation. J Lubr Technol Trans ASME. 104, 1982, April; 168-72.

Presents a theoretical analysis of lubrication of rolling contact bearings considering cavitation with a non-Newtonian lubricant, obeying the power law model. Piezo-viscous and deformation effects are neglected. The analysis reveals that as the flow behaviour index increases, the load capacity increases and the point of cavitation as well as the point of maximum pressure is shifted towards the center of contact.

ROLLING, SLIDING, SURFACE CRACKING

170. KANETA (Motohiro), SUETSUGU (Minoru) and MURAKAM (Yukitaka). Analysis of surface cracking in lubricated rolling sliding contacts. J Jpn Soc Lubr Eng. 31, 5; 1986, 322-28.

Growth behaviour of a surface crack formed on lubricated rolling/sliding contact surfaces is compared with that formed on point contact surfaces. It is found that there is large difference between these contact states in regard to the tensil mode fatigue growth due mainly to the two types of oil hydraulic effect excerted by the oil entering into the crack, though the growth behavious by the shear mode, which causes the fatigue growth of a tiny crack, is almost similar regardless of the contact states.

SCUFFING, SLIDING CONTACT

171. YAMAMOTO (Yuji) and MATSUI (Satoru). Effects of mineral oil viscosity on scuffing resistance in sliding contacts Part 1. J Jpn Soc Lubr Eng. 29, 4; 1984, 279-86.

Examines the scuffing resistance of mineral oils of different viscosity grades in sliding contact with a modified Timken tester. It was found that at low sliding speeds where EHL film built up was thinner than that at higher sliding speeds, scuffing did not occur unless the contact conditions became sufficiently severe, even if continuous breakdown of the EHL film took place. On the other hand, at higher sliding speeds, continuous breakdown of the EHL film was apt to lead to the occurrence of scuffing.

SHAFTSEAL, LEAKAGERATES

172. BEATTY (PA) and HUGHES (WF). Turbulent two phase flow in face shaft seals. J Tribol Trans ASME. 109, 1; 1987, 91-99.

Presents a general theory for the calculation of leakage rates and quasi-static opening force for aligned face seals operating in a turbulent two phase flow regime. Seal stiffness and its relationship to opening force are discussed. Also discusses the calculation of mass leakage rates and opening force under choked and unchoked conditions. The phenomenon of all liquid chocked flow is explained.

SINGLE PASS RUB TEST

173. KENNEDY (FE). Single pass rub phenomena-analysis and experiment. J Lubr Technol Trans ASME. 104, 4; 1982, Oct; 582-88.

Describes an experimental and analytical investigation of the temperatures and deformations which occur during a single traverse of a steel blade lip over a flat, smooth fully dense copper surface. Experimental work was carried out on a peudulum type test device, with forces, rub energy, surface temperature, and residual deformation being defermined for each single-pass rub test. Also develops an analytical model for studying the thermal and mechanical factors influencing surface temperature in these single pass rubs. The analytical surface temperature predictions were varified by the experimental results.

SLIDING, SURFACE TOPOGRAPHY

174. JAIN (VK) and BAHADUR (S). Surface topography changes in polymer-metal sliding. J Lubr Technol. 105, 4; 1983, Oct; 526-33.

Investigates sliding between high density polyethlene and poly (vinyl chloride) pin ends and a steel disk periphery. Data were obtained, both along and perpendicular to the direction of sliding. A number of surface roughness parameters, the slop density, and radius of curvatures and heights of asperities were calculated using a Fortran IV computer program. Analysis shows that the surface parameters undergo a marked variation during the early part of sliding, but the variation is statistically insignificant during the later part.

SNOW TEMPERATURES

175. GLENNE (B). Sliding friction and boundary lubrication of snow. J. Tribol Trans ASME. 109, 4; 1987, Oct; 614-17.

Considers dry, wet, compaction, and impact resistances to understand the basic facts of snow tribilogy. Describes that these mechanisms and their aggregate effect are reviewed and modeled for cold and warm snow temperatures. Also considers snow moisture and wet lubrication.

SOLID PARTICLES, CAVITATION

176. PRAKASH (J) and SINHA (Prawal). Theoretical effect of solid particles on the lubrication of journal bearings considering cavitation. Wear. 41, 1977, 233-49.

The theory of micropolar fluids, characterized by the presence of solid particles, is applied to the lubrication of an infinitely long journal bearing considering cavitation. The prominent features of the presence of solid particles in the lubricant is an increased effective viscosity, especially the thin films. The effects of microstructure or solid particles are presented graphically. Tables are given to facilitate the comparison of the results obtained by using Reynolds boundary conditions with those obtained by using half Somnerfeld boundary conditions.

SPINDLE BEARING, CONTINUOUS FEED

177. DZUBA (VI). Lubricating system with a continuous feed of oil in the form of a film. Sov Eng Res. 5, 6; 1985, Jun; 14-5.

Investigates that in lubricating system the amount of the oil supply in the piping, the formation of a moving oil film and the continuity of its arrival at the friction pair are affected by the air pressure, the stokes of the metering spoil etc. For a continuous, extremely small oil supply, which provides merely for creation and maintenance of a thin oil film on the friction surfaces in the cavity of the spindle bearings, a lubricating system has been devised which provides a flow for an oil film along a feed pipe.

SQUEEZE EFFECT

178. MARUI (E), KATO (S), MATSUBAYASHI (T) and KOBAYASHI (A). On the squeeze effect of lubricant between two rough surfaces. J Tribol Trans ASME. 109, 4; 1987, Oct; 696-703.

Examines the surface roughness effect on the squeezing mechanism. Introduces the approximate equation of squeeze flow for that surfaces. In case of rough surface the approximate equation is extended.

The calculation of lubricant squeezing by the extended equation agrees well with the experimental results in both cases of circular and rectangular surfaces. Measures the oil film thickness which is change with elapsed time. It is larger than the surface roughness, here micro squeeze effect may occur. Approximate surmula is constructed to estimate the squeeze effect on rough surfaces. The flow of lubricant and the surface asperèties are modeled to simplify the calculation. Also examines the influence of surface roughness on the load carrying capacity which generates by squeeze effect.

SQUEEZE FILM, VISCOELASTIC FLUID, HUMAN JOINTS

179. MANOHAR (K) and NIGAM (KM). Squeeze film lubrication of a viscoeleastic fluid with reference to human joints. <u>Wear</u>. 70, 1981, 283-93.

Squeeze film lubrication between two approaching surfaces is considered with reference to normally loaded human joints. The fluid between the surfaces is viscoelastic. The upper surface is a rigid rectangular plate and the lower surface is a porous rectangular plate composed of three thin layers with differing porosities. Analytical closed form solutions are obtained for the pressure distribution and the load-carrying capacity. The effects of the viscoelastic behaviour of the synovial fluid and the effects of the porosity variation of the cartilage on the pressure and on the load carrying capacity are presented graphically.

STEEL, GEARS, PITTING

180. KRISHNAMURTHY (S) and RAO (Ramamohan). Effect of 0.14%C steel gears. Wear. 120, 3; 1987, 289-303.

Surface treated low carbon steel gears are tested in a back to back gear test rig. The failure of the gears is by pitting and the contract stress-pitting life curve has been established. Wear particle analysis of the lubricating oil was carried out to analyse the nature of the failure. Study reveals that sursulf treatment on low carbon steel gears considerably improves their performance. The cumulative wear particle concentration at the pitting limit has been suggested as a basis for predicting the onset of failure of the gears.

SURFACE, ELASTIC DEFORMATION

181. HOU (Keping). New numerical technique for compiting surface elastic deformation caused by a given normal pressure distribution. J Tribol Trans ASME. 107, 1; 1985, 128-31.

Deals with a new numerical method for computing the elastic normal surface displacement field caused by a given normal pressure distribution. The pressure function is approximated by a piece wise bignadratic polynomial on the whole domain analyzed. The deformation of every node is expressed as a linear combination of the nodel pressureswhose coefficient can be combined into a deformation matrix. Consequently the interative calculation of elastic deformation is simplified and the amount of work is greatly reduced. It has been proved, inaddition that the numerical accuracy of the new method is higher that that of some others.

TESTING, AMSTERWEAR TEST MACHINE

182. HABIG (KH) and FEINLE (P). Failure of steel couples under boundary lubrication : Influence of steel composition, microstructure, and hardness. J Tribol Trans ASME. 109, 4; 1987, Oct; 569-76.

Investigates the failure of tribo systems by means of an Amster, wear, test, machine with two contacting and rotating devise that were immersed into a tempered oil bath. The load was increased in steps until failure was indicated by an increase of the coefficient of friction. Result reveal a strong influence of the chemical composition and of the microstructure of the steels while hardness does not show an influence. Failure is restricted if protective reaction layers can form on the stressed surfaces. Most of the alloying elements reduce the formation of such layers failure load is lowered by them. Unalloyed ferrite is able to form thick reaction layers causing a high failure load. Less reactive components of the microstructure like cementite martensite and all austenite decrease the failure load.

TESTING TITANIUM, THIN FILM

183. TING(Bond-Yen), RAMALINGAM (S) and WINER (WO). Experimental investigation of the film to substrate bond strength of sputtered thin film using a smi quantitative test method. J Tribol Trans ASME. 107, 4; 1985, 478-82.

Report on the experimentally measured adhesion strength of thin films of titanium and titanium intride deposited an aluminum and stainless steel substrates. A semi qualitative test method presented to measure the film to substrate bond strength. The test result show that the surface cleaning and preparation procedures used prior to film deposition dominate thin film adhesion.

THERMAL HYDRODYNAMIC, ANALYSIS HYDROSTATIC EXTRUSION

184. MAHDAVIAN (SM). Thermal hydrodynamic lubrication analysis for hydrostatic extrusion of a work hardening metal. J Tribol Trans ASME. 108, 3; 1986, July; 368-37.

Presents a thermal hydrodynamic lubrication theory that covers the wide range hydrostatic extrusion of metals over a wide range of operating conditions. This thermal hydrodynamic lubrication analysis is extended to the forming of a strain hardening metal. Also considers an exponential stain hardening mode for the billet. The effect of viscous heating in both intel and work zones, and surface temperature of work somes are included. The results are compared with previous theoretical models. It indicates that thermal strain hardening effects play an important role in determining hydrostatic extrusion for high reduction of area and high strength metals.

TWO PARALLEL COAXIAL DISK, SQUEEZE FILM,
DYNAMIC LOAD

185. HARNOY (A). Squeeze film flow of elastic fluids at steady motion and dynamic loads. J Tribol Trans ASME. 109, 4; 1987, Oct; 691-95.

Investigates the role of elasticity of the fluid in a squeeze film flow between two parallel coaxial disks. Analyzes elastic fluids of low Deborats numbers where the stress relaxation process is a first order effect to the dominant zero order effect of the viscosity. Results shows reduction in the load capacity for a steady speed squeeze action. Also predicts an improvement in the lubrication performance at dynamic loads.

VISCOELASTIC INCOMPRESSIBLE FLUID
INERTIA

186. ROY (Jyotirmoy Sinha) and BISWAL (Bhagaban). Effect of fluid inertia on the film pressure between two axially oscillating parallel circular plates with a viscoelastic lubricant. 1981, 163-68.

A viscoelastic incompressible fluid between two parallel circular plates separated by a small distance with sinusoidal axial vibration of the top plate including fluid inertia terms was considered. Flow phenomena were characterized by non-dimensional parameters such as the Reynolds number Re and the elastic number S. An iteration method was used to solve the non-linear equations. Also studies the effect of Re and S on the fluid pressure.

WATER BASED

187. SINGER (HAIMI) and ARLENE (Kaljee). Water based lubrication a major break through. S Afr Mech Eng. 36, 4; 1986, 106-111.

A new water based lubricant invented in South Africa has passed tests at Iscor and has proved itself to be better than its oil based counterpart. Gives information or senfluids, its characteristics, general industrial we and application.

WATER, RIGIDITY, EEFECT, VIBRATIONS

188. ARONOV (V), D'SOUZA (AF), KALPAKJIAN (S) and SHAREEF (J). Experimental investigation of the effect of system rigidity on wear and friction-induced vibrations. J Lubr Technol Trans ASME. 105, 2; 1983, Apr; 206-11.

Presents an experimental data and a physical model of the effects of normal load and system rigidity on the friction and wear process with water lubrication The transition from wild the severe friction and wear was found to be independent of the system rigidity but dependent on the normal load. As the normal load is increased further, it reaches another critical value, which depends on system rigidity at which high frequency selfexcited vibrations are generated. These oscilliations exhibit a coupling between the frictional and normal degrees of freedom. It is shown that mild wear rate increasing with the normal load and also with the system rigidity.

W E A R

189. VERBEEK (HJ). Tribological systems and wear factors. Wear. 56, 1; 1979, 81-92.

Investigates that the compilation and analysis of practical data concerning numerous different cases of wear load to a useful conception of wear evaluation. It is limited to tribo systems where abrasive and adhesive were occurs. Also listed data from the literature and from actual measurements which specify all the relevant circumstances and conditions for separate cases of wear. The "wear factors" for each item listed in calculated from the worn volume, the load and the sliding distance. All the wear factors are grouped in a restricted number of main tribo groups. This demonstrates the trend of wear factor levevels for different systems and the scatter per group. Further evaluation is illustrated with the help of giagrams.

ABRASION, DEBRIS ANALYSIS

190. MASHLOOSH (KM) and EYRE (TS). Effect of attack angle in abrasive wear. Met Mater. 2, 7; 1986, Jul; 426-30.

Developes a reciprocating wear test which allows this parameter to be studied in isolation from all others. Wear debris has been examined and its specific features vary with the wear conditions and the type of metal or alloy being worn. This indicates that debris analysis is a powerful tool not only in wear investigation but also in the diagnosis of wear problems and in the applications of condition on health monitoring of machine systems.

MATHEMATICAL MODEL

191. TORRANCE (AA). New approach to the mechanics of abrasion Wear. 67, 2; 1981, Mar; 233-57.

Compares the results of abrasive wear tests with the results of scratch tests designed to simulate abrasion. Shows that they are apparently in contradiction. It is shown that this contradiction arises because the scratch tests fails to simulate on important mechanism of metal removal, side wall stripping.

Describes the results of some scratch tests which are designed to investigate this and a mathematical model which predicts both metal removal and forces is developed. Briefly discusses the implications of the model.

SOLID PARTICLES

192. VENOGRADOV (VN). Abrasive wear in a stream of solid particles. Sov Eng Res. V, 12; 1984, 27-30.

As a result of numerous investigations into the behaviour of various materials in a gas abrasive stream, it is established that the basic factors of external action of the material are the angle of attack, the velocity of the stream of abrasive particles, the properties and concentration of the abrasive material as well as the characteristic of the medium in which wear takes place. However to intensity of wear depends not only on the factors of external action but also on the physical mechanical properties of the material.

ADHESIVE

193. RABINOWICZ (Ernest). Least Wear. Wear. 100, 1-3, 1984, 533-41.

Describes three types of adhesive wear, namely severe wear, moderate wear and buruishing wear. Also discusses the transition between them. Buruishing or material removal on a molecular scale, represents the least possible amount of adhesive wear, but little is known regarding the magnitude of the wear rate and methods of ensuring that a sliding system will operate in the buruishing regime. This is unfortunate because for many sliding system, especially those using unlubricated surfaces, there is no likelihood of achieving an acceptable life unless operation of the sliding surfaces in the buruishing regime can be assured.

ANALYSIS

194. SCOTT (Douglas). Wear Analysis. Phys Technol. 14, 3; 1983, 133-39.

Outlines the problems associated with wear. The techniques of wear detection, measurement and analysis are discussed.

ANISOTROPIC, MICROSTRUCTURES

195. HORNBOGEN (Erhard). Description and wear of materials with heterogeneous and quisotropic microstructures. Wear. 11, 4; 1986, Oct; 391-402.

Discusses some principal features of materials which consist of more than one microstructural component. Such microstructures are characterized by volume fractions, type and arisotropy. Attempts have been made to derive quantitative models for the description of bulk wear rates as functions of the volume fractions and properties of two phase, the properties of the interface and the different types of microstructure. A change of volume fraction can be associated with a transformation of the type of microstructure into, another and thus with a discontinuous change in wear resistance. For anisotropic structures tensors can be used for a complete description of the tribological properties.

BIMODEL FAILURES, MECHANISM

196. HARRIS (CJ), WEBSTER (M), SAYLES (RS) and MACPHERSON (PB). Bimodel failure mechanisms in tribological components. Reliab Eng. 4, 3; 1983, 169-80.

Describes the affects of bimodel failures in tribological components in terms of possible mechanisms of surface interaction and failure. Emphasis is on the influence of surface topography and self generated wear debris on the mechanisms causing bimodel wear encountered with common tribological components. This mechanism is shown to be prevalent in many fatigue results published for rolling contact and by random sampling experiments is demonstrated to be a real effect and not just an arti facts of sampling.

CHEMOMECHANICAL, INTERACTION, THEORY

197. CIFTAN (Mikael) and SAIBEL (Edward). Rebinder effect and wear. Wear. 56, 1; 1979, Sept; 69-80.

Discusses the relationship between the rebinder effect and wear through the general form of the chemomechanical interaction. An attempt has been made to merge the theories of the Russion School and that of westwood etc. into one unified theory which can be made quantitative and used to explain many facts of the wear of metallic and nonmetallic materials.

CHEMOSTRESS EFFECTS

198. CIFTAN (M) and SAIBEL (E). Chemostress effect and wear. Wear. 88, 1; 1983, June; 23-26.

Introduces a theory of chemomechanical interaction. The variation in the Gibbs chemical potential with mechanical stress is calculated explicity using statistical thermodynamics and many body theory. This quantity is the chemostress coefficient and the related effect is the chemostress effect. The theory gives the basis for the quantitative explanation of stress corrosion cracking, pitting corrosion, fretting corrosion, the Rebinder effect and enhanced chemical activity on crystal surfaces. It suggests methods of arresting corrosion by controlling the charge distribution of electrolytes near the surface under consideration and explains observed correlations between the zero of connection of the chemostress effect to the running in process in tribology.

COEFFICIENT, COMPUTATION

199. RABINOWICZ (E). Wear coefficient magnitude, scatter, uses. J Lubr Technol Trans ASME. 103, 2; 1981, 188-194.

One of the key factors in the analysis of a wear problem is the computation of the wear coefficient for a comparison with the value to be anticipated for this application. Typical values of adhesive wear coefficients for a variety of materials and lubricants are presented, and the values compared with those arising from the wear modes of abrasion, corrosion and fretting. A major uncertainty arises from the fact that wear coefficients show considerable variation both in repeat testing and in the testing of different materials that presumably should have the same wear coefficient. Quantitative values for the scatter encountered in adhesive wear situations are given and discussed. Various uses of the wear coefficient in the analysis sliding systems are illustrated.

CORROSION, CAST IRON

200. YAHAGI (Y) and MIZUTANI (Y). Corrosive wear of cast iron in sulphuric and. J Tribol Trans ASME. 109, 2; 1987, April 238-42.

Discusses the mechanism of corrosive wear of cast iron. The wear rate of cast iron and the corrosion potential and current were measured in sulphuric acid for that purpose. The corrosive wear rate of cast iron was found to reach a maximum at around 35 wt. per cent sulphyric acid concentration and increase with load and acid temperature. The increment of corrosion current due to friction was found to correlate with the corrosive wear of cost iron. It has been concluded that the combined action of the changed properties and profile of corroded rubbing surfaces and the mechanical destruction due to wear causes the drastic corrosive wear, which is much greater than the wear seen with either alone.

CORROSION, EXPERIMENTAL STUDY

201. LAZAREV (GE). AFANAS'EV (KI) and GAMAZOV (NI). Study of the corrosion-mechanical wear process. Sov J Frict Wear. 5, 5; 1984, 99-104.

Investigates that most of the metal loss in corrosion-mechanical wear takes place as a result of corrosion intensified by friction. Corrosion with friction takes place in the areas of actual contact, where the corrosion rate is hundreds of thousands of times greater than on the metal surface without friction. Developes a setup and technique that make it possible to determine experimentally the corrosion, both over the entire rubbing surface and in the areas of real contact.

CORROSION, MECHANISM

202. LAZAREV(GE). Mechanism of corrosion, mechanical wear. Sov J Frict Wear. 5, 4; 1984, 131-33.

Describes the mechanisms of corrosion-mechanical wear, which amounts to the fact that during friction the deformation of the material in the areas of actual contact is accompanied by destruction of the passivating films and the appearance of juvenile surfaces on which the corrosion processes increase. The corrosion in the areas of actual contact during friction is several orders greater without friction.

CORROSIVE AND ABRASIVE, ORE GRINDING

203. IWASAKI (I), RIEMER (SC), ORLICH (JN) and NATARAJAN (KA). Corrosive and abresive wear in ore grinding. Wear. 103, 3; 1983, 253-67.

Discusses the relative significance of corrosive and abrasive wear in ore grinding. Ball wear tests were carried out with magnetic taconite and quartzite under different conditions, namely dry, wet and in the presence of an organic liquid. Also evaluates the effect of different modes of aeration and of pyrrhotite addition on the ball wear using mild steel, high carbon low alloy steel and austenitic stainless steel balls. Also indicates that abrasive wear plays a significant role in ore grinding in the agsence of sulfides, and reological properties of the ore slurry influenced such wear.

DEFORMABLE STRUCTURE

204. ASTRAKHAN (A Kh). Solution of the contact problem for a system of deformable bodies with the presence of wear. Sov J Frict Wear. 6, 3; 1985, 21-27.

Examines the wear process in a tribotechnical system in which the connection between the friction assemblies is realized by a deformable structure. Also propose a method for calculating the junction wear including numerical calculation of the system at fixed times and analytic solution of the differential equation of wear. Also analyzes the stability of the solution and studies qualitatively the behaviour of the solution. The method is illustrated by analyzing a shaft on wearable supports.

DETERIMENTAL, EFFECT, ECONOMIC STUDY

205. BALASUBRAMANIAN (TV) and LAL (Jagdish). Detrimental wear : Its economics in tribological structures. J Inst Eng. 60, 1; 1980, 103-106.

Discusses the detrimental effects of wear in machines and industrial plants. Also discusses the maintenance cost of operation involving tribological situations. Gives a brief account of economic losses generated by surface interactions in tribological structures and various stages of the availability of plant for production use are worked out.

DISLOCATION DIFFUSION, SELECTIVE TRANSFER REGIME

206. POLYAKOV (SA) and RYBAKOVA (LM). Dislocation diffusion mechanism of wear reduction in selective transfer. Sov J Frict Wear. 6. 5; 1985, 107-113 .

Examines the mechanisms of resorption of the dislocation clusters formed in the surface layers of metals during friction. It is shown that only mechanism making it possible to significantly reduce the dislocation density in the planar clusters parallel to the surface during friction in the selective transfer regime is dislocation climb. Evaluates the degree of vacancy supersaturation in the thin surface layers of coppers on the basis of election microscope and roentgenographic data. And the magnitude of the dislocation climb displacements under the action of the given vacancy supersturation is calculated. It is shown that the calculated dislocation displacement is comparable with the size of the region and reduced dislocation density. The analytic dependence of the dislocation density on the degree of vacancy supersaturation in the servovit film with the action of lubricants having different chemical activity is obtained.

EFFECT, FERROGRAPH ANALYZER

207. SANTANAM (N). Effect of wear debris on wear in rolling sliding motion. Wear, 90, 2; 1983, Oct; 261-67.

Investigates the effect of wear particles on wear using a four ball extreme pressure lubricant test apparatus. Examines the wear particles present in both filtered and unifiltered oil samples by using a duplex ferrograph analyzer and a bichromatic unicroscope. The wear track widths were measured for various wear modes and were found to increase if the weaf debris was recirculated. The size of wear particles increased with test duration.

EROSION, FATIGUE AND ENERGY THEORY

208. ZOLOTAR (AI) and SHEIVEKHMAN (AO). Material erosion resistance evaluation based on a combinations of the fatigue and energy theories of wear. Sov J Frict Wear. 5, 2; 1984, 93-100.

Discribes the analytic relations for the rate of erosive wear of materials impacted by a stream of solid particles which are used to determine the specific energy capacity of the material, characterizing its wear resistance. For this the damage process is examine by combining the fatigue and energy theories of wear.

ESTIMATION

209. DUNAEVSKY (VV). Measurement of microscopic wear. J Tribol Trans ASME. 108, 1; 1986, 35-41.

Describes a method for determining a linear wear comparable to a surface roughness height. The method allows estimation of the wear by result of profilometry of the worn surface only. Presents formulas which provides wear evaluation for surfaces modeled by Gaussian random fields. The method simplifies the technology of precise wear measurements, improves their accuracy, and increases the availability of profilometrical ways of wear analysis.

EXPERIMENTAL INVESTIGATION

210. KRAUSE (Hans) and LEHNA (Heribert). Investigation of tribological characteristics of rolling-sliding friction systems by means of systematic wear experiments under well defined conditions. Wear. 119, 2; 1987 153-74.

Systematic experimental investigation of wear due to rolling sliding friction shows that well defined test conditions enable clear frends in stationary wear rates to be detected. Even slight trend deviation in measured wear rates may be ascribed to the effects of small changes in test conditions.

FRETTING

211. SATO (Jun'iti). Recent trend in studies of fretting wear. J Jpn Soc Lubr Eng. 30, 12; 1985, 853-58.

Presents a critical review of recent studies of fundamental aspects of fretting wear. Reports practical cases of incidents of fretting damage, i. e. broken crank pin bolt in a marine diesel engine and a worn ball bearing in a fatigue testing machine. Discusses the mechanism of fretting damage from the point of Mindlin's theory, the stress distribution on the surface and the direct observation of fretting phenomena. The critical amplitude for causing damage was determined from experimental results. Also reviews the effect of temperature, surface treatment and lubricants on fretting wear.

FRETTING, COMPARATIVE STUDY

212. LYONS (H) and COLLINS (JA). Failure prediction criteria for fretting wear. J Mech Des Trans ASME. 104, 3; 1982, Jul; 619-625.

Dynamic excitations in machines and structure may lead to a form of wear caused by fretting, which may cause premature mechanical or structural failure. Fretting wear has been evaluated under a variety of conditions, and a linear prediction model is compared to experimental results.

FRETTING MECHANISM

213. HAMDY (M.M.), OVERS (M.P.) and WATER HOUSE (R.B.). New high temperature fretting wear test rig J Phys E. 14, 7; 1981, 889-94.

Describes a new apparatus for fretting wear investigation. This rig can be used at elevated temperatures having the features of measuring and recording simultaneously the frictional force and the normal force between the contacting surfaces. Also either the rider displacement, velocity or ace acceleration can be monitored and recorded. Data obtained assist in the determination of fretting mechanisms and some results are presented.

FRETTING, VARIABLES, SURFACE TEMPERATURE

214. ATTIA (MH) and D'SILVA (NS). Effect of mode of motion and process parameters on the preduction of temperature rise in fretting wear. Wear, 106, 1-3; 1985, Nov. 203-24.

Investigates the effect of reciprocating motion, in contrast with the case of unidirectional sliding, on the surface temperature rise. Presents the results in dimensionless form for a wide range of variables encountered in fretting wear. The flash temperature concept ered in fretting wear. The flash temperature concept is reviewed in the light of the theory of thermal constriction resistance to establish the accuracy and limitations of esisting models and to evaluate the sensitivity of the surface temperature to various process parameters, namely material properties, work hardening, oxide film and surface roughness.

HERTZIAN CONTACT

215. WATKINS (RC). Use of the hertzian dimension in wear scar analysis (application to four-ball results). Wear. 91, 31; 1983, Nov; 349-54.

Under elastohydrodynamic conditions compression of the contact surfaces gives the well known calculable hertzian contact conditions. For wear data analysis it is proposed that the wear dimension should be divided by the corresponding hertzian dimension to give a dimension less wear parameter. The use of this technique in four ball testing was shown an improvement in seizure load evaluation and has thrown some light upon changes in the wear regime in this ng.

HOT SPOTS, TOOL STEEL

216. QUINN (TFJ) and WINER (WO). An experimental study of the "Hot Spots" occurring during the oxidational wear of tool steel on spphire. J Tribol Trans ASME. 109, 2; 1987, April; 315-19.

Describes some preliminary experiments with tool steel pins sliding against a rotating spphire disk without lubrication. Result shows (i) that mild (oxidational) wear of the pin surface can obtained with this combination of materials (ii) that the "hot spots" between the pin and the disk surfaces can be seen and photographed for size analysis and (iii) that the temperature of the hot spots can be estimated from the photographs. The objective being to complement the optical analyses and therby provide information about the number, size and temperature of the hot spots. Also discusses the relevance of these estimates to the mechanism which involves in mild (oxidational) wear.

INTERDICIPLINARY THEORY

217. STOLARSKI (TA). Contribution to the theory of lubricated wear. Wear. 59, 2; 1980, Mar; 309-22.

Proposes a mathematical analysis to describe a complex interdisciplinary theory involving some controversial subsidiary topics. The new model is based upon Archard's theory and Halling and Finkin's solution, and incorporates the concept of the fractional film defect and the theory of Johnson etc. concerning the division of the load, between the lubricating film and the contacting asperities under circumstances where both contribute to supporting the load. Theoretical and experimental results are compared.

MAGNETIC DISK SURFACE, TESTING

218. MISRA (A). Oscillatory wear tester for testing wear and elurability of magnetic disk surfaces. IBM Tech Discl Bull. 27, 9; 1985, 53000.

Describes that the traditional tests used by disk manufacturers for accelerated wear and durability measurement of the magnetic disk surface are the start/ stop and accelerated wear tests. In both tests it takes days to weeks to get useful data. Thus for the quality control of the manufacturing process and for the development of new types of surface coatings, there has been a great need for a tester which could do wear testing in much shorter times. A new tester has been designed and built which does the wear and durability testing in less than 1/2 hour.

MAGNETIC FIELD, SLIDING VELOCITY

219. MAJU (MK) and RADHAKRISHNA (A). Wear of non-magnetic materials in the presense of a magnetic field. Wear. 58, 1; 1980, Jan; 49-58.

Describes that during rubbing contact the presence of a magnetic field improves the wear behaviour of the material with the lower magnetic permeability. Investigates the wear of brass and stainless steel rubbing against wild steel. The relative hardness of the materials also controls the useful range of application of a magnetic field; the influence of temperature was also considered. Suggests a criteria for the range of sliding velocity within which the application of a magnetic field would be useful.

MASS AND LINEAR, STUDY

220. DIVAKAR (P), KOTIVEERACHARI (B) and REDDY (Krishna BG). Study of wear characteristics of different materials. Wear. 85, 2; 1983, Mar; 151-61.

Studies the wear characteristics of different materials including plastics and determine the variation in mass and linear wear with normal load and speed. Derives an empirical relation for the mass wear of brass sliding against steel in terms of the normal load. Also investigates the variation in mass and linear wear with material hardness. Studies the different sliding pairs to assess a minimum wear rate.

MATERIALS, RESISTANCE

221. CHANDLER (Harry E). Key developments in materials that inhibit wear. Metal Progress. 126, 2; 1984, Jul; 23-31.

Presents a view of international developments in parts that resist wear, materials for resistance to wear, wear resistant coatings and processes that impact wear resistance to components.

MATERIAL SELECTION PROCEDURE,IN-SITU

222. BALL (A) and WARD (JJ). Approach to material selection for corrosive-abrasive wear by systematic in-situ and laboratory testing procedures. Tribology Int. 18, 6; 1985, Dec; 347-51.

Presents the procedures by which it is possible to select engineering materials for mechanical engineering design through a programme of in situ and laboratory wear testing. It is shown that a limited number of in-situ tests must be undertaken to establish the validity of a laboratory test. Examples are used to illustrate the procedure. The procedures are applicable to similar investigations for example the wear of ground engaging tools and communication devices.

MEASUREMENT

223. YOST (FG). Two profilometric measurements of wear. Wear. 92, 1; 1983, Dec; 135-42.

Argues that wear volume measurements in many pin on disk wear tests are very tenuous. This is especially so far ion-implanted materials. As more reliable substitutes for wear measurements, wear frack profile area and maximum wear depths are suggested. It is shown that these measurements are easily made in the modern profilometer facility. Simple statistical calculations are used to show that profile area and track length can be multiplied to obtain the wear volume when adjacent wear track profiles are highly shape correlated. Defines maximum wear depth and describes depth measurements by an extreme value distribution. These statistics, based on the measurements are then used to estimate speciman reliability.

MECHANICAL VIEW

224. GODET (Maurice). Third body approach : A mechanical view of wear. Wear. 100, 1-3; 1984, 437-52.

The third body approach highlights the many feature which are common to different types of materials in different types of rubbing contacts. It suggests that a picture which globally coherent from a mechanical point of view, in that it obeys as a first step the laws of equilibrium and continuity can be presented. That picture, which is strongly inspired by lubrications theory is presented together with its many implications in both fundamentals of tribology and industrial solutions.

MECHANISM, CEREMIC, TESTING

225. HISAKADO (T). Wear mechanism of ceremics and surface topography. J Tribol Trans ASME. 108, 1; 1986, 9-15.

Theoretically analyze the effect of the number of contact points, total area of the cross-sections of grooves ploughed by harder asperities and depth of plastic zone on the coefficient of friction and wear by assuming that the shapes of harder contact asperities were semicylindrical with the hemispheric ends. Wear tests for various ceremic pins sliding against a ceremic disk were carried out in unlubricated sliding to verify the theory. Also indicated the existence of a new criterion controlling the wear rates of ceremics.

—, SPHERICAL PARTICLES

226. WANG (You), GAO (Caiqiao) and WANG (Dianliang). Study of the formative mechanism of spherical wear particles. Wear. 108, 3; 1986, 285-94.

Studies speherical wear particles produced by sliding wear processes by means of a scanning electron microscope and an energy dispersive X-ray analyser. Direct and indirect evidence from the examination demonstrates spherical particles to be a product of the local wear surface which is melted i.e. droplets of the melting metal solidify into spherical particles.

MICROSCOPIC, MEASUREMENT

227. DUNAEVSKY (VV). Measurement of local microscopic Wear. J Tribol Trans ASME. 108, 1; 1986, 35-41.

Describes a method for determining a linear wear comparable to a surface roughness hight. This method is given to calculate mild wear which is based on the measurement of worn surface only. Practical formulas involves in wear evaluation for surfaces modeled by Gaussian random fields. The method simplifies the technology of precise wear measurements, improves their accuracy, and increase the availability of profilometrical ways of wear analysis.

OXIDATIONAL STUDY

228. BUINN (TFJ). Review of oxidational wear. Part II : recent developments and future in oxidational wear research. Tribol Int. 16, 1983, 305-15.

Describes recent developments involving determination of the activation energies and arrhenius constants for oxidation during wear. Discusses some of the research into the use of measurements of oxide film thickness to deduce the contact temperatures at the real areas of contact. Covers the effect of oxygen partial pressures on the wear of metals. Also describes an oxidational wear theory relevants to elevated ambient temperatures, and discusses the trends in oxidational wear research in the 1980's.

OXIDATIONAL THEORY, DEVELOPMENT

229. QUINN (TFJ). SULLIVAN (JL) and Rowson (DM). Origins and development of oxidational wear at low ambient temperatures. Wear. 94, 2; 1984, Mar; 175-91.

Reviews the origins and development of the oxidational theory of mild wear under conditions where the ambient temperatures are sufficiently low that no significant oxidation can occur outside the instantaneous red areas of contact between two sliding surfaces. Emphasizes the importance of heat flow analysis for calculating surface temperatures and the division of heat at the sliding interface, especially in used for explaining the wear rates obtained in some pin-on disc experiments with low alloy steels.

PIN ON DISK MACHINE

230. BISWAS (S), PRAMILABAI (BN) and BISWAS (SK). Pin on disk machine. Indian J Technol. 22, 7; 1984, 250-51.

Describes the design of a pin on disk machine used for studying sliding wear process. Sliding occurs between a stationary pin and rotating disk. In this design, normal load can be varied from 0 to 100 N, and rotational speed from 0 to 100 rpm. Continuous recordings of friction and wear can be obtained simultaneously.

POLYETHERE THERKETONE

231. VOSS (H) and FRIEDRICH (K). On the behavious of short-fibre reinforced peek composites. Wear. 116, 1; 1987, 1-8.

Investigates the wear behaviour of short glass and carbon-fibre-reinforced composites of polytethere ther-ketone under extremely different types of wear loading. Sliding wear tests against smooth surfaces reveals that the addition of short fibres reduced the wear rate under certain conditions of sliding speed and contact pressure, especially with carbon fibre reinforcement. The wear rate is also influenced by a change in the matrix morphology due to a thermal treatment.

PROGNOSES

232. BECKMANN 'Gottfried), DEIRICH (Peter), GRAU (Peter) and PETZOLD (Matthias). Representation of the micro-hardness distribution and its consequences for wear prognoses. Wear. 107, 3; 1986, Feb; 195-212.

Outlines that if small imcrocontacts arise and there is a transition from elastic to plastic contacts, wear prognoses must take account of the statistical behaviour of hardness. Describes the method of recording hardness measurement. It is a practical way of determining the distribution functions of the microhardness. Also considers statistical analyses of these measurements, representations of the results and expected applications in wear investigations.

233. BEER BOWER (Alan). Wear rate prognosis through particle size distribution. ASLE Trans. 24, 3; 1981, Jul; 285-92.

Diagnosis of wear regime can be made by examination of the wear particles interms of the number or weight fraction in each size range. Consideration of the alternatives leads to the conclusion that a weibull plot by weight is the most useful. Application of this diagnosis to simplified wear rate equations can result in more meaningful prognosis of life expectancy. The relations of the more familiar SOAP, ferrograph and chip detector methods are explored.

RATE DATA

234. LHYMN (C). Statistical analysis of wear rate data. J Tribol Trans ASME. 109, 4; 1987, Oct; 594-97.

Deals with the statistical methodology in the analysis of wear rate data. The wear rate data of glass fiber reinforced polyethylene terephthalate has been analyzed statistically using the wear life time model together with the two parameter weibull distribution function. The specific wear rate versus normal load curve has been given a theoretical explanation . The emprirical model being derived from the concepts of crack propagation and delamination physics.

RESEARCH

235. CZICHOS (Horst). Review on Wear research-activities in the FRG. Wear. 1oo, 1-3; 1984, Dec; 579-89.

An overview of wear research is given consisting the three parts, (i) a brief historical review of early wear research which started on a scientific basis in the 2920's (ii) a survey of current research activities, including the scope and contents of an operational West German Tribology Research Program and (iii) a discussion of trends and avenues for further research.

RESEARCH, JAPAN

236. SASADA (Tadashi). Wear Research in Japan : Trends and future directions. Wear. 100, 1-3; 1984, 561-77.

Reviews Japanese research on wear of materials during the last 100 years. Discusses the recent trends in research work which include the lubrication mechanism of surrounding gas molecules in wear, mutual transfer and growth theory for the formation process of wear particles, the fatigue concept, the seizure of metals, the effect of oil lubricants on wear and abrasive wear, and brief comments are mode on them. Also mentioned the academic societies in the field of wear in Japan and their activities.

RESISTANCE, LOW FLAMMABILITY, HYDRAULIC FLUID

237. RYABOSHAPKA (VM), VENTSEL (ES), MOZHAROV(MV) and LIVADA (GF). Study of antifriction characteristics and wear resistance of materials in low-flammability hydraulic fluids. Sov J Frict Wear. 6, 5; 1985, 118-26.

Presents techniques for studies of the anti-friction characteristics and wear resistance of materials in low-flammability working fluids of the classes HFA, HFB, HFC and HFD. It is shown that the structural materials have differing antffriction and wear characteristics when lubricated with the different low-flammability fluids. Also presents data which is useful in selecting materials and fluids in combination that will minimize hydraulic equipment friction pair wear.

ROTATING BANDS

238. MONTGOMERY (RS). Wear of projectile rotating Bands. <u>Wear</u>. 101, 4; 1985, 347-56.

Rotating or driving bands are bands of relatively soft materials surrounding a projectile. They have a number of functions. The important function is probably that they produce stablizing rotation of the projectile when they are engraved or keyed into the rifling. Discusses that excess wear of projectile rotating bands has a number of important negative consequences including inaccuracy and short rounds. There are two distinetly different mechanisms of wear. At low speeds the beginning of motion, wear is by adhesion, abrasion and even, under some conditions, scuffing.

SCANNING, ELECTRON MICROSCOPE

239. LIM (SC) and BRUNTON (JH). Dynamic wear ng for the scanning electron microscope. Wear. 101, 1; 1985, 81-91.

A pin-on disk wear ng has been constructed to operate inside the scanning electron microscope to allow direct, high magnification, observation of wear asit occurs. The wear process is recorded on video tape and the variations in normal load and and frictional force are measured and recorded using a data-logging system. Experiments using this ng shows the formation of sheet or flake like debris when high purity copper pins slide on case-hardened mild steel disks. The amount of debris produced over the same sliding distance is found to be influenced by small variations in the surface roughness of the disks.

SLIDING, CYCLIC PLASTIC DEFORMATION, TESTING

240. GLARDON (R), CHAVEZ (S) and FINNIE (I). Simulation of sliding wear by cycle plastic deformation under combined stresses. J Eng Mater Technol Trans ASME. 106, 3; 1984, Jul; 248-52.

Describes a mechanical test which simulate the conditions occuring in sliding wear. It involves the cyclic plastic deformation of metals under combined compression and shear. Reports the results of tests on six alloys and correlates with those from wear tests. An expression is proposed on this basis for the sliding wear rate which is based on material behaviour during cyclic plastic deformation and involves three material properties. The implications of this expression for the wear rate are discussed and directions for future work are suggsted.

SLIDING, HALF PLANE, TRANSIENT CONTACT

241. AZARKHIN (A) and BARBER (JR). Transient contact of two sliding half planes with wear. J Tribol Trans ASME. 109, 4; 1987, Oct; 598-603.

Discusses the contact problem of two sliding half planes with wear. Studies the transient contact of two sliding bodied with a simple geometry. The model employs the archard law of wear in which the rate of material removal is propertional to pressure and speed of sliding. Problem formulates in terms of two governing equations with unknown pressure and heat flux at the interface. The equations are solved numerically, using appropriately chosen Green's functions. Starts with a single area of contact. The contact area shrinks as a result of rictional heating and thermal expansion. This leads to further localization of pressure and temperature. Areas carrying load are removed by wear and contact waves elsewhere. The system develops a cyclic behaviour in which contact and non contact areas interchange.

—, MICROSTRUCTURAL DEFORMATION, MEASUREMENT

242. BLAU (PJ). Measurement and inter pretations of sliding wear damage in metals. J Tribol Trans ASME. 107, 4; 1985, 483-90.

Researches on sliding friction and wear of metals has involved studies of sub-surface microstructural deformation. Also discusses the difficulties of measuring deformation and analyzing the implication of such studies on several bases : (1) defining the physical extent of sliding induces deformation (2); making appropriate measurements and deformation for complex tribological conditions and (3) correlating microstructure wear damage with the measurable friction forces on sliding contacts.

—, SURFACE DISLOCATION MODEL

243. MARCINKOWSKI (MJ). Surface dislocation model of wear. J Mater Sci. 19, 4; 1984, 1296-1306.

Proposes a model of sliding wear, based upon the concept of surface dislocations. A dislocation cell structure is created in the plastically deformed surface layer, which in turn gives rise to shear crack initiation at the interface between this surface layer and the underformed interior of the body. These shear cracks then grow with subsequent delamination of the surface layers. The most important parameter in this theiry is the rate of work hardening of the materials in question.

—, SYSTEM, EVENTS

244. RIGNEY (DA), CHEN (LH), NAYLOR (Malcolm GS) and ROSENFIELD (AR). Wear processes in sliding systems. Wear. 100, 1-3; 1984, Dec; 195-219.

Outlines a sequence of events involved in sliding wear. Local contacts cause large plastic strains in either or both solid components. The plastic deformation changes the wear surface microstructure in ways which make the material unstable to local shear. This in turn produces transfer of pieces of deformed material which are further deformed and mixed with counterface material and environmental components to produce ultrafine-grained material. The very fine microstructure in this transfer material is stablized by the mixing in (mechanical alloying) of a second phase. The relative hardness of the transfer material and the adjacent substrate material affects the surface topography, the smoothness of sliding and the nature of the wear debris. Loose debris is commonly derived from the transfer material.

TESTING

245. SRIDHARAN (G). Improvised sliding wear testing device. Exp Tech. 10, 6; 1986, 26-7.

Sliding wear is measured by the amount of material worn out when an indenter slides back and forth over sample material. A sliding wear testing mechanism was needed to tackle wear problem of a certain component. The situation prompt to device the following improvisation. The proposed device is an attachement to a shaping machine. A reciprocating motion is provided by this host machine. The proposed mechanism provides a constant downward vertical force. This force acts on the sample under investigation, which is held horizontally on the shaping machine's table.

STEEL, RUNNING-IN

246. SUZUKI (M) and LUDEMA (KC). The wear process during the "Running In" of steel in lubricated sliding. J. Tribol Trans ASME. 109, 4; 1987, Oct; 587-91.

Reports the results of research on steel sliding on steel through the regime of contact severity that produces "running in". Both mineral oil and engine oil were used to produce different results. Electrical contact resistance was measured for a number of sliding conditions along with measurements of the coefficient of friction, the wear rate, the oxide film thickness and surface topography. The purpose is to determine the role of surface finish and film formation in the running in process. Emphasis is on the role of oxygen in boundary lubrication.

SURFACE FEATURE, STUDY, CELLULOSE ACETATE

247. LENG (Andrew). Use of cellulose acetate replicas in tribology. S. Afr Mech Eng. 34, 3; 1984, 77-79.

Monitoring changes in the surface feature of components can be done non-destructively by studying replicas of these surfaces. As each type of wear produces characteristic surface features the type and severity of wear for each component can be obtained.

TANGENTIAL STRESS

248. JAHANMIR (S). Relationship of tangential stress to wear particle formation mechanism. Wear. 103, 3; 1985, 233-52.

Experimental results and observations by scanning electron microscopy have demonstrated that the process of wear particle formation under lubricated sliding conditions is greatly affected by the tangential stress. In these experiment, the normal load was kept constant and the tangential stress was varied by changing the friction coefficient using different friction reducing additives in the base oil. The predominant coefficient attained by the friction modifier.

TESTING

249. EVDOKIMOV (Yu A). Method of accelerated wear resistance tests on mechanical engineering products. Sov Eng. Res. 3, 7; 1983, 3-4.

Considers a method of accelerated friction and wear tests on materials, components and units of machines. Studies the method which is based on the use of the physical similarity of the process and the scale factor is taken into account. Also gives the formulae and a table of coefficients for computation.

THERMAL RESEARCH

250. QUINN (TEJ) and WINER (WO). Thermal aspects of oxidational wear. Wear. 102, 1-2; 1985, 67-80.

Briefly reviews the early research on the thermal aspects of wear, where most of the attention had been on deducing the hot spot temperatures which occur between sliding surfaces. Also describes more recent work in which the effect of oxide films on hot spot temperatures is deduced. Also discusses the division of frictional heat.

THERMOCHEMICAL, NITROGEN, STAINLESS STEEL

251. ILLANES (CAMPILLO BF) and SARKAR (AD). Wear of thermmochemically produced nitrogen stainless steel. J Tribol Trans ASME. 108, 3; 1986, July; 334-39.

Examines the wear resistance of two steel and with varying nitrogen contents introduced of nickel-rudced or nickel-free Fe-18 per cent er alloys. Thermochemically produced stainless steels with varying nitrogen content were slid dry on high carbon martensitic steel counterfaces using a pin bush machine. The running in-wear was high but the steady state wear decreased with increased nitrogen contents of the steel. A work hardened layer formed on the pins, the degree of hardening increasing with the nitrogen content of the steels. The hard pins caused a considerable amount of wear of the bushes, possibly, by ploughing. The pins were by transfer and oxidation, and by interfacial shear and probably, britte fracture of the work hardened layer at heavy load.

TOPOGRAPHICAL CHANGES, EXPERIMENTAL STUDY

252. SUGIMURA (Joichi) and KIMURA (Yoshitsugu). Characterization of topographical changes during lubricated wear. Wear. 98, 1-3; 1984, 101-116.

Studies the profiles of the wearing surfaces with the help of experiments on lubricated wear. Introduces two types of cross-correlation coefficients. One compares the profiles obtained at the same position before and after sliding for a fixed duration and the other compares the profiles at different positions on the same wear track. It is found that the former represents a characteristics of the wearing mode, while the later quantitatively gives the degree of two dimensionality of the topography.

TRIBOSPECTORAL, CHARACTERISTICS

253. RYZHOV (EV), ZAPOROZHETS (VV), VARYUKHNO (VV) and GONCHARENKO (Yu. N). Influence of electromechanical treatment on specimen surface layer homogeneity and wear resistance. Sov J Frict Wear. 5, 1; 1984, 19-23.

Presents an evaluation of the influence of electromechanical treatmont on surface layer uniformity on the basis of the tribospectral characteristics, which makes it possible to determine the optimal surface, hardening regime for parts operating under specific contact loading conditions. Presents results of a study of the changes of the tribospectral characteristics of the surface layer of specimens before and after fretting-corrosion-wear-resistance testing.

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PART THREE
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